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SOME LIMITATIONS OF VAGOTOMY IN THE TREATMENT OF PEPTIC ULCER:

A CRITICAL FOLLOW-UP ANALYSIS OF FIFTY CASES*

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INTRODUCTION

We are presenting in this report, a careful and critical follow-up analysis of 50 cases of intractable, non-obstructing duodenal and marginal ulcer treated by transthoracic vagotomy. In none of these cases was any supplemental surgical procedure performed so that changes in the course of the disease could not be referred to more than one operative factor. This is a continuing survey, the end results of which will not be complete for many years to come. However, the findings, even at this early date, have been sufficiently convincing to encourage us to publish this interim analysis.

HISTORICAL

It is not our purpose to review the voluminous literature on surgery of the vagus nerves. We have been impressed with the fact that the clinical use of vagotomy, like many other surgical procedures, occurs in cycles. In reviewing the literature it became apparent that vagotomy was utilized in the treatment of peptic ulcer over a generation ago in a number of the European clinics. Although follow-up reports are meager, it is obvious that the procedure did not live up to expectations since it virtually dropped out of the literature after 1921 until revived by Dragstedt more than 20 years later. Attempting to discover the reasons for its original clinical use and its subsequent abandonment, the early European literature was reviewed and appropriate references made thereto. In the early part of this century experimental work on animals[1-5] subjected to vagotomy produced conflicting observations regarding the pro-

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duction of peptic ulcers, spasm of the pyloric sphincter, and gastric atony. Based upon the work of Foerster who resected the posterior root nerves of the D-X, XI, and XII for the pain of tabetic crises, Exner,[6] in 1911, was the first to resect the vagus nerves in the treatment of peptic ulcers. The publication of his results was followed by trials of this operation in several of the larger clinics of Europe. Several different methods of achieving a complete division of the vagus nerves were tried, some being admittedly inadequate. On the other hand, many of the clinics are noted for the thoroughness of their work in other fields, and on this basis it must be assumed that their claim of complete division of the nerves is substantially correct. Bircher[7] published his results in 1920 in a series of 20 cases of peptic ulcer and claimed a good result in 13 cases, fair in four, no benefit in one case, and two recurrences. He does not mention the time interval between operation and evaluation of results, nor is there any later follow-up in the literature.

After revival of the procedure by Dragstedt, vagotomy was utilized by many clinics with uniformly encouraging results as reported in the literature.[8-29] In these reports, the good results claimed for vagotomy must be considered in the light of short follow-up periods and the fact that a majority of cases received, at the same time, gastroenterostomy, gastric resection, pyloroplasty or some other surgical procedure which alone might be expected to influence the final result.

From the literature it is difficult to gain a clear concept of the influence of vagotomy *alone* on the clinical course of the disease process. Variations in the type of cases selected, the presence or absence of obstruction, and incompleteness of follow-up observations, are all factors which serve to obscure the issue. Certainly those cases upon whom other surgical procedures are performed concurrently, cannot be considered in any analysis which attempts to answer the question. The warning notes sounded by Lahey,[30] Walters[31, 32] and Bockus,[33] have been borne out by our findings which rather strikingly fail to confirm the more optimistic observations of other workers in the field.

CLINICAL STUDY

With these thoughts in mind, the surgical staff of this hospital undertook to attempt an answer to the problem in August, 1946. It was felt desirable to determine the long term effect of vagotomy alone upon the clinical course of selected patients with duodenal or marginal ulcer. Accordingly, certain criteria were established in order to select as homogeneous a group as possible. Further to insure uniformity, each case was presented before operation to the entire surgical staff and no case was selected for vagotomy unless it met the following criteria:

1. Symptoms of intractable pain, chronic bleeding, or both.
2. Failure to control symptoms by adequate medical regimen.
3. Evidence of active ulcer by roentgen ray.
4. No retention, clinically or by roentgen ray.

Patients with gastric ulcer or with acute hemorrhage were not considered suitable candidates for vagotomy. Since the study began in August, 1946, 54 cases have been subjected to vagotomy with one death,—a mortality rate of 1.9 per cent. Of these 54, only 50 are reported in this series. The two most recent cases have not been observed sufficiently long to permit evaluation of results. One case of duodenal ulcer with obstruction was treated by gastro-enterostomy and subdiaphragmatic vagotomy. Another patient received a cardioesophagostomy for achalasia of the esophagus. Because of a concurrent intractable duodenal ulcer, vagotomy was performed at the same time. Although good results have been observed in both of these cases after one year, they are not included in the series because of the uncertainty of ascribing the results to the vagotomy or to the associated surgical procedure.

The remaining 50 cases, on which this report is based, include 41 patients with duodenal ulcer and nine with marginal gastrojejunal ulcerations. Patients were all of the male sex with ages ranging from 21 to 58 years with an average of 37 years; 44 were white and six colored. The duration of symptoms varied from four months to 30 years, with an average of six years. All cases had intractable ulcer pain, and 64 per cent, in addition, gave a history of one or more episodes of gastro-intestinal bleeding. All 50 cases were operated upon through the lower left transthoracic route, with or without rib resection. In each case the vagus nerve trunks were isolated, transected, and a segment of nerve removed for histologic verification.

Postoperatively an indwelling Levine tube was kept under constant suction for three days, after which the patient was placed on a liquid diet. Persistent atony was treated by continuous gastric suction, parenteral feedings, and urecholine (Carbaminoyl-Beta Methylcholine Chloride), 5 to 10 mg. three times daily.

While in the hospital patients received a standardized preoperative work-up which included histamine gastric analyses, overnight secretion studies, insulin (Hollander) tests and gastro-intestinal roentgenograms. These were repeated in the early postoperative course and again upon readmission for follow-up examination.

IMMEDIATE POST-OPERATIVE RESULTS

Symptoms. In all except two cases there was complete or nearly complete relief of ulcer pain. In a number of cases it was difficult to evaluate this immediate effect because of the predominance of symptoms of gastric atonia.

Gastric Secretion. Twelve-hour overnight secretion which averaged 970 cc. was reduced to 290 cc. in the early postoperative period. Maximum free hydrochloric acid values in the overnight specimen dropped from an average of 44 units preoperatively to 23 units postoperatively. Insulin hypoglycemia tests were performed pre- and postoperatively according to the method described by Hollander.[34] Where postoperative responses were equivocal, the test was repeated one or more times. In the early postoperative period Hol-

lander tests showed a negative response in 82 per cent, indicating adequate section of the vagus nerves. In 6 per cent the test was not performed because of severe symptoms of obstruction which promptly developed. One of these patients was the single postoperative death encountered. The second developed such severe obstruction that he required gastric resection three weeks after vagotomy. In the third case the patient was uncooperative and left the hospital. In two cases (4 per cent) the insulin response was equivocal and in four cases (8 per cent) was positive. Of these last six cases (12 per cent) in which complete vagus section was not demonstrated, results were "good" in four (8 per cent), "fair" in one (2 per cent) and "failure" in one (2 per cent). As will be seen, the end results in this small group do not differ in pattern from the remainder of the cases in which complete vagotomy was demonstrated.

Complications. Pleural effusion was diagnosed in 40 per cent of the cases postoperatively and probably occurred to some extent in an even greater number. This complication was not of great moment and subsided in all cases either spontaneously or after thoracentesis. Two cases (4 per cent) developed atelectasis and pneumonitis. One case (2 per cent) developed a wound infection and one case (2 per cent) acute pericarditis with effusion which cleared spontaneously.

By far the most troublesome complications developed as a result of disturbances in gastric motility. Fullness in the epigastrium, belching, pyrosis, regurgitation and vomiting were noted in varying degrees of severity in 80 per cent of the cases early in the postoperative course. This was associated with loss of stomach tone, gastric enlargement, diminished peristalsis, retained gastric contents and delay in emptying time. Barium studies to determine functional changes of the stomach revealed normal motility in only 40 per cent of the cases in the postoperative period. Ten per cent showed mild gastric dilatation; 40 per cent showed moderate enlargement of the stomach or six hour gastric retention, or both; 20 per cent showed enlargement over twice the normal size or more than 50 per cent gastric retention after six hours, or both.

Five patients (10 per cent) developed early in the postoperative period such severe and unrelenting atony that further surgery was necessary. Gastric resection was performed in four of these five cases from three to 15 weeks postoperatively after strenuous efforts by the use of gastric suction and urecholine had failed. The fifth case was in such poor condition from pre-existent hepatic disease that only gastroenterostomy was performed. This failed to halt the patient's downhill course and he died three months and 20 days following vagotomy.

FOLLOW-UP STUDIES

Few reports in the literature indicate the method of securing follow-up data. It is presumed that questionnaire responses supplied much if not all of the information in the majority of cases. We have been impressed with the serious limitations of this method of evaluating symptomatic results granting

that it may, at times, be the only practical means of securing information. Personal interview associated with careful laboratory and roentgen ray studies form, in our opinion, a method of evaluation least likely to result in interpretative error.

For such reasons all patients in this series were requested to reenter the hospital for a brief period while necessary studies could be accomplished. Only three cases (6 per cent) were not subsequently hospitalized. Two cases (4 per cent) had admissions to other hospitals from which information was received. All other cases (90 per cent) have been readmitted to this hospital from one to four times for careful evaluation and laboratory examinations which included overnight secretion studies, gastric analysis, insulin (Hollander) tests, and fluoroscopic and roentgen ray studies of the gastro-intestinal tract. Excluding the five cases of early failure, follow-up has been secured in all cases extending from six months to two and a half years, an average of 18 months. One of us has personally interviewed each patient in an attempt to equalize the personal equation in the evaluation of symptomatic results. Data on all 50 cases are summarized in Table I.

Symptoms. Evaluation of symptomatic results was based on the presence or absence of postoperative ulcer pain and/or bleeding, or of the secondary effects of denervation, and the patient's estimate of his condition as compared with his preoperative status. The following definitions are given for the assigned adjective rating.

Excellent:	No symptoms of ulcer or atonia.
Good:	Some ulcer symptoms, but definitely ameliorated, or slight to moderate symptoms of atony,—or both.
Fair:	Return of ulcer symptoms or severe atony or both, but condition better than preoperative state.
Failure:	Return of ulcer symptoms at least to preoperative severity,—or severe atony requiring further surgery, or both.

Results are summarized in Figure 1. Failures are divided arbitrarily into "early" and "late,"—all five (10 per cent) of the "early" failures required further surgery within three and a half months of vagotomy—because of persistent atony with obstructive symptoms. "Late" failures (24 per cent) had initial relief followed by recurrence of symptoms from three to 24 months (average 10) postoperatively. Three of this group came to gastric resection and one to gastroenterostomy from six to 27 months after vagotomy.

Out of the 17 failures, "early" and "late," nine cases came to further definitive ulcer surgery. One case (No. 22) was the single postoperative death in the series. It is noteworthy that three cases (Nos. 14, 17, 31) later developed marginal ulcers, two following gastric resection and one following gastroenterostomy.

Pain. Although initial relief of ulcer pain was noted in 80 per cent of the cases, return or persistence of characteristic postprandial ulcer distress was

TABLE I

Case No.	Age	Race	Type of Ulcer	Symptoms P = Pain. B = Bleeding	Duration, years	Insulin (Hollander) test post-operative + = Positive − = Negative ± = Equivocal U = Unknown	X-Ray Findings: Early Postoperative (< 3 mos.) Ulcer A = Not visualized 1 = Niche 2 = Active 3 = Inactive	X-Ray Findings: Early Postoperative (< 3 mos.) Atony 1 = Severe 2 = Moderate 3 = Slight 4 = None	X-Ray Findings: Follow-Up (> 3 mos.) Months Post-operative	X-Ray Findings: Follow-Up (> 3 mos.) Ulcer 1 = Niche 2 = Active 3 = Inactive U = Unknown	X-Ray Findings: Follow-Up (> 3 mos.) Atony 1 = Severe 2 = Moderate 3 = Slight 4 = None U = Unknown	Follow-Up Symptoms (*Early Failure) Months Post-operative	Follow-Up Symptoms (*Early Failure) Ulcer O = Symptom free + = Mild or moderate ++ = Severe U = Unknown	Follow-Up Symptoms (*Early Failure) Atony O = Symptom free + = Mild or moderate ++ = Severe U = Unknown	Evaluation	Remarks
1	41	W	D	PB	3	−	1	4	24	1	4	30	++	O	Failure	Initial healing of ulcer followed by recurrence of pain and bleeding and ulcer niche 2 yrs. p. o.
2	46	W	D	PB	5	−	2	2	12	1	2	12	O	O	Excellent	Symptom free despite dilated atonic stomach and persistent ulcer on X-ray
3	38	C	D	P	3	±	A	1	27	1	3	27	+	++	Fair	Slight relief. Further hospitalization required for ulcer pain
4	58	W	D	PB	4 mo.	−	2	2	27	3	2	27	++	O	Failure	Symptom free for 22 mos. when pain and bleeding recurred. Lymphosarcoma of stomach, removed after 27 mos.
5	33	W	D	PB	6	−	2	1	20	2	2	27	+	+	Fair	Pain relieved but has recurrent bleeding, atony, and persistent ulcer.
6	36	W	D	PB	3½	−	2	2	18	3	4	26	+	O	Good	Pain relieved for 2 yrs., followed by mild pain and occasional black stools.
7	40	W	D	PB	1½	−	3	4	27	3	4	27	O	O	Excellent	Symptom free
8	39	W	D	PB	3	−	1	2	25	3	4	25	++	+	Failure	Incomplete relief followed by return of all preoperative symptoms 2 yrs. later
9	26	W	D	PB	2½	−	2	2	3	3	4	24	+	O	Good	Complete relief for 16 mos. followed by mild ulcer pain. No bleeding
10	35	W	D	P	2½	−	3	4	24	4	2	24	+	+	Good	Occasional mild ulcer pain with moderate symptoms of atony.
11	26	W	D	P	6	−	2	2	17	1	2	24	+	+	Fair	Return of ulcer pain after 6 mos., but less severe. Moderate atony.

12	29	C	D	P	3	−	3	3	3	3	4	23	+	O	Fair	Ulcer pain partly relieved. One episode of bleeding
13	30	W	D	P	4	+	A	2	−	U	U	19	+	O	Good	Some ulcer pain persists but improved
14	32	W	D	PB	3	−	2	4	17	1	4	22	++	+	Failure	Symptoms returned after 3 mos. Gastric resection after 17 mos., followed by marginal ulcer
15	40	W	D	PB	11	+	1	4	−	U	U	18	O	+	Good	No pain despite apparently incomplete vagotomy. Mild atony
16	30	W	D	PB	1	−	A	2	−	U	U	15	O	+	Good	Pain relieved. Moderate atony. No bleeding
17	29	W	D	P	7	−	3	2	10	1	1	11	++	++	Failure	Symptoms returned after 3 mos. Gastroenterostomy at 11 mos., followed by marginal ulcer. Gastric resection at 22 mos.
18	30	W	D	PB	5	−	1	4	14	1	4	14	O	+	Good	No pain or bleeding. Moderate symptoms of persistent atony
19	26	C	D	PB	4	−	2	4	14	3	4	20	+	+	Good	Mild pain. No bleeding. Persistent atony and diarrhea.
20	29	W	D	PB	4	−	3	4	11	1	3	19	O	O	Excellent	Symptom free despite persistent ulcer crater
21	22	W	D	PB	4	−	2	2	12	3	4	19	+	++	Fair	Ulcer pain nearly completely relieved. No bleeding. Severe persistent atony and diarrhea
22	36	W	D	P	3	U	1	1	−	−	−	4	++	++*	Failure	Died 3 mos. 20 days postoperatively from gastric atony and hepatic insufficiency
23	29	W	D	PB	5	−	2	4	6	1	4	6	++	O	Failure	Preoperative ulcer pain returned after 4 mos. Gastric resection at 6 mos.
24	24	W	D	P	1	−	2	2	−	U	U	17	O	O	Excellent	Symptom free
25	33	C	D	PB	5	−	2	3	17	3	4	17	O	O	Excellent	Symptom free
26	56	W	D	PB	26	+	2	4	14	1	4	16	++	O	Failure	Pain and bleeding recurred after 4 mos. Incomplete vagotomy
27	42	W	D	PB	5	U	A	1	−	−	−	3 wk.	++	++*	Failure	Gastric resection 3 wks. postoperatively for unrelenting atony.
28	35	W	D	PB	5	−	2	2	8	3	2	17	O	+	Good	No pain or bleeding. Moderate symptoms of atony
29	30	W	D	PB	5	−	A	2	9	3	2	9	O	+	Good	No pain or bleeding. Moderate symptoms of atony
30	25	W	D	P	4	−	2	4	9	3	4	9	O	O	Excellent	Symptom free

* Three weeks duration of marginal ulcer. Duodenal ulcer symptoms for 28 years.

TABLE I (*Continued*)

Case No.	Age	Race	Type of Ulcer	Symptoms P = Pain, B = Bleeding	Duration, years	Insulin (Hollander) test post-operative: + = Positive, − = Negative, ± = Equivocal, U = Unknown	X-Ray Findings: Early Postoperative (< 3 mos.) Ulcer: A = Not visualized, 1 = Niche, 2 = Active, 3 = Inactive	X-Ray Findings: Early Postoperative (< 3 mos.) Atony: 1 = Severe, 2 = Moderate, 3 = Slight, 4 = None	X-Ray Findings: Follow-Up (> 3 mos.) Months Post-operative	X-Ray Findings: Follow-Up (> 3 mos.) Ulcer: 1 = Niche, 2 = Active, 3 = Inactive, U = Unknown	X-Ray Findings: Follow-Up (> 3 mos.) Atony: 1 = Severe, 2 = Moderate, 3 = Slight, 4 = None, U = Unknown	Follow-Up Symptoms (*Early Failure) Months Post-operative	Follow-Up Symptoms (*Early Failure) Ulcer: O = Symptom free, + = Mild or moderate, ++ = Severe, U = Unknown	Follow-Up Symptoms (*Early Failure) Atony: O = Symptom free, + = Mild or moderate, ++ = Severe, U = Unknown	Evaluation	Remarks
31	56	W	D	PB	30	−	A	1	3½	1	1	15	++	++*	Failure	Gastric resection at 3½ mos. for unrelenting atony. Marginal ulcer 5 mos. later
32	24	W	D	PB	4	−	2	2	9	3	3	15	+	+	Good	Mild ulcer pain. No bleeding. Mild symptoms of atony
33	21	W	D	P	4	−	A	2	15	1	2	14	++	++	Failure	Pain recurred after 13 mos. Moderately severe atony
34	42	W	D	PB	5	−	2	2	14	1	2	14	++	+	Failure	Pain recurred after 10 mos. No bleeding. Moderate atony
35	52	W	D	PB	15	−	A	1	−	U	U	14	O	+	Good	No pain or bleeding. Moderate symptoms of atony
36	55	W	D	PB	7	−	A	1	7	3	1	13	O	O	Excellent	Symptom free despite persistent gastric atony and retention
37	37	W	D	PB	10	−	2	2	13	3	2	13	O	O	Excellent	Symptom free
38	29	C	D	P	5	−	A	1	−	−	−	2	++	++	Failure	Gastric resection at 2 mos. for persistent pain and severe atony. Died of pulmonary embolus, 27 days later
39	32	W	D	P	5	±	A	1	7	2	1	7	+	O	Good	Complete relief for 3 mos. followed by mild ulcer pain

40	38	W	D	PB	6	−	1	2	12	3	2	12	O	O	Fair	Pain relieved. Massive hemorrhage 9 mos. postoperatively
41	41	W	D	PB	14	+	1	4	6	3	4	7	+	O	Good	Complete relief for 6 mos. followed by mild ulcer pain. No bleeding
42	28	C	M[2]	PB	1	−	1	4	6	3	4	6	++	O	Failure	Pain recurred after 3 mos. No bleeding. X-ray shows spasm of efferent jejunal limb
43	40	W	M[2]	P	3	−	1	2	9	3	4	9	+	O	Good	Complete relief for 3 mos. followed by mild ulcer pain
44	46	W	M[1]	P	4 mo.	−	1	1	−	−	−	9	+	++*	Failure	Gastric resection at 2½ mos. for persistent pain and extreme atony and retention
45	54	W	M[1]	P	15	−	1	2	11	1	2	22	O	O	Excellent	Symptom free despite ulcer niche and gastric retention
46	56	W	M[2]	P	3 wk.**	−	1	4	14	1	2	19	++	+	Failure	Recurrence of pain and bleeding after 9 mos., with persistent ulcer
47	33	W	M[1]	P	13	−	2	3	16	3	2	16	O	+	Good	Pain relieved. Moderate symptoms of atony
48	46	W	M[2]	P	2	U	1	3	−	U	U	11	++	+	Failure	Pain recurred after 3 mos. Moderate symptoms of atony
49	57	W	M[1]	PB	13	−	1	3	9	1	2	9	+	O	Good	Mild pain. No bleeding. Ulcer persistent
50	51	W	M[2]	PB	3	−	1	4	7	1	4	13	O	+	Good	Partial relief of pain for 7 mos. Thereafter no pain. No bleeding. Mild symptoms of atony

[1] Marginal ulcer following gastroenterostomy.
[2] Marginal ulcer following gastric resection.
** 3 weeks duration of marginal ulcer. Duodenal ulcer symptoms for 28 years.

noted to occur to some extent in 28 cases (56 per cent) in the short follow-up period to date. Being aware of the possibility that future pension ratings might influence the veteran's complaints we attempted a correlation between symptoms and roentgen ray findings of all cases in the follow-up period as follows:

No symptoms	— Normal roentgen-ray findings	27 per cent
No symptoms	— Positive roentgen-ray findings	20 per cent
Symptoms	— Positive roentgen-ray findings	27 per cent
Symptoms	— Normal roentgen-ray findings	13 per cent
Either factor unknown.....		13 per cent

Bleeding. Of 32 cases complaining of bleeding preoperatively, 7 (22 per cent) noted bleeding at some time during the follow-up period. Two additional cases who had no preoperative bleeding, noted tarry stools after operation. Knowing the long interval that may occur between bleeding episodes, the fact that bleeding appeared in one-fifth of our cases even in the short follow-up period (18 mos.), throws serious doubt on the alleged protective value of vagotomy against this phase of the ulcer process.

Roentgen Ray Findings. **Ulcer Healing.**—In order to determine the effect of vagotomy on healing of the ulcer, gastro-intestinal series were performed one to four times in all but six cases during the follow-up period. The results are summarized in Figure 2.

To insure uniformity 80 per cent of the fluoroscopic examinations and review of all of the roentgen ray films were performed by one roentgenologist. Criteria for activity of a duodenal ulcer were those customarily accepted by roentgenologists—namely, the demonstration of an ulcer niche or a tender, deformed bulb with irritability and/or spasm. For marginal ulcer activity the demonstration of a niche was required.

Roughly, two out of five cases in this series were noted to have active ulcers in the follow-up period. On many of these, healing had been demonstrated in the earlier postoperative months with reactivity being noted up to two years after vagotomy. More frequent roentgen rays, particularly if taken in coincidence with exacerbations of ulcer symptoms, would most likely increase the observed incidence of recurrent ulcer.

Atonia.—This term is used to include the alterations in motility nearly uniformly observed fluoroscopically following parasympathetic denervation of the stomach. Characteristically they include gastric enlargement, diminution in tonus, decreased peristalsis, and retention of gastric contents. That this retention is not due to spasm of the pyloric sphincter was repeatedly demonstrated by the fluoroscopist who could manually express barium through a flaccid pylorus into the duodenum. The extreme degrees of these changes were noted early in the postoperative course. Although tonus was regained in the majority of cases, 18 (36 per cent) had definite atony with six hour gastric retention from seven to 27 months after operation. This stands in contrast to the recent findings of Ritvo, *et al.*[35] The follow-up observations are presented in Figure 3. These roentgen ray findings coupled with additional observations on func-

tional alterations noted in the gallbladder, large bowel and kidneys will form the material for another paper.

Secondary Symptoms. Closely correlated with roentgenologic observations of gastric atonia are those symptoms associated directly with section of the vagus nerves. Again the early symptoms of bloating, fullness, regurgitation,

FIG. 1

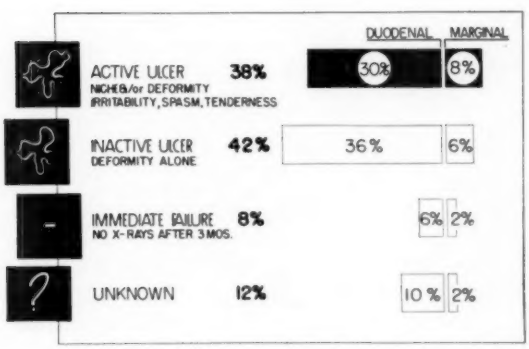


FIG. 2

FIG. 1.—Results observed six to 30 months post-operatively.

FIG. 2.—End results of vagotomy as determined by roentgen ray appearance of ulcer.

vomiting and diarrhea either disappear or are greatly ameliorated in the majority of cases after several weeks. In contrast to some earlier reports, persistent diarrhea was not an outstanding complaint in the follow-up period, occurring in only two cases (4 per cent). Persistence of symptoms, however, is not as infrequent as previous reports have led us to believe. Excluding the early failures due to unremitting atonia, 49 per cent of cases during the follow-up period

presented significant symptoms which in 9 per cent formed a source of serious disability. Considering the entire series, only 46 per cent escaped severe or prolonged symptoms attributable to nerve section.

Gastric Secretion. In general, 12-hour overnight secretion volumes tended to increase during the follow-up period with values intermediate between the preoperative and early postoperative levels. Free HCl was repeatedly observed in cases which had demonstrated achlorhydria shortly after vagotomy. In at least six cases (12 per cent) insulin tests previously negative or achlorhydric became equivocal or positive, usually associated with recurrence of symptoms. We cannot explain this observation, but we doubt that it is due to regeneration of the vagus nerve fibers. Considerable difficulty was experienced in the interpretation of some results and there were many conflicting tests done only a few days apart.

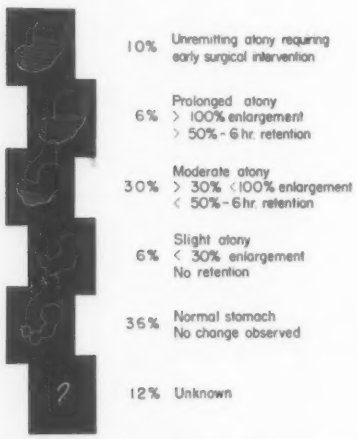

10% Unremitting atony requiring early surgical intervention
6% Prolonged atony > 100% enlargement > 50% - 6 hr. retention
30% Moderate atony > 30% < 100% enlargement < 50% - 6 hr. retention
6% Slight atony < 30% enlargement No retention
36% Normal stomach No change observed
12% Unknown
?
EFFECT OF VAGOTOMY ON GASTRIC MOTILITY AS DEMONSTRATED BY X-RAY

FIG. 3.—Roentgen ray observations of secondary changes following denervation.

CASE REPORTS

Brief protocols of all cases are contained in Table I. Pertinent observations are offered in the 17 cases classified as failures.

Case 1.—A 41-year-old white male first noted hematemesis three years before admission. Roentgenograms revealed a duodenal ulcer. Subsequently he had many episodes of pain, hematemesis and tarry stools necessitating hospitalization on three occasions. At the present admission roentgen rays revealed an active duodenal ulcer with a niche. Overnight gastric secretion was 1550 cc. with a free acid of 55 and a total acid of 75 units. Transthoracic vagotomy was performed on August 30, 1946, with relief of pain. Repeated postoperative insulin tests showed a negative response. He was relieved of pain for three months, after which mild symptoms were noted until two years after operation, when there was full return of preoperative pain and tarry stools. Three follow-up roentgenograms at three, seven and 14 months had demonstrated a healed ulcer, but the fourth series done two years postoperatively revealed an active ulcer with a niche (Fig. 4).

Comment. In this case vagotomy was followed by relief of symptoms and healing of the ulcer. The effect was temporary, however, with return to preoperative status after two years.

Case 4.—A 58-year-old white male presented a four-month history of postprandial abdominal pain, hematemesis and tarry stools. Roentgenograms revealed a large duodenal ulcer crater. Acid values were within normal limits. The patient had two further hematemeses and tarry stools while under medical treatment over a period of two months. On November 20, 1946, transthoracic vagotomy was performed with relief of symptoms. Insulin test was negative. The patient was free of ulcer pain or

bleeding for 24 months. Roentgen rays at three, six and 11 months showed healing of the ulcer and a moderate degree of atony. Twenty-four months after vagotomy the patient had abdominal distress and hematemesis for which he was readmitted. Roentgen rays now revealed, (Fig. 5), a large filling defect of the greater curvature of the stomach. Laparotomy was performed 27 months after vagotomy and a large tumor occupying the posterior wall of the distal half of the stomach was resected (Fig. 6). Histologic examination revealed the tumor to be a reticulum cell lymphosarcoma. A portion of the resected duodenal bulb showed no evidence of ulcer.

Comment. The question naturally arose whether the tumor existed at the time of vagotomy 27 months before. All films were reviewed by the entire radiology staff and it was definitely felt that the patient originally had a duodenal ulcer which healed after vagotomy. The tumor mass of the stomach could not be observed even in retrospect in the many films taken during the follow-up period. It is possible, but not likely, that the atony secondary to nerve section may have altered the radiologic criteria for detection of the earlier stages of the tumor. Certainly if transabdominal exploration had been done initially, this question would not still be unanswered.

Case 8.—A 39-year-old white male gave a three-year history of ulcer pain with several tarry stools and one episode of perforation nine months before admission. Overnight secretion was 840 cc. with a free acid of 80 and a total acid of 113 units. Roentgen rays revealed a duodenal ulcer with a niche. Vagotomy was performed on January 28, 1947, with relief of pain and an uncomplicated postoperative course. Insulin hypoglycemia test showed complete achlorhydria. He noted only moderate epigastric fullness and belching and remained free of ulcer symptoms for 2 years. Fourteen months after operation he developed typical symptoms and signs of acute appendicitis and appendectomy was performed.

After two years, ulcer pain returned with its preoperative severity. Although he has secured partial relief from diet and antacids, he has lost much time from work because of pain. At 25 months roentgen rays revealed a duodenal ulcer niche and the insulin hypoglycemia test was now equivocally positive.

Comment. This case demonstrates the temporary effect of vagotomy on ulcer symptoms, roentgen ray findings, and the cephalic phase of gastric secretion.

Case 14.—A 32-year-old white male presented a three-year history of intractable ulcer pain with hematemesis on four occasions, the last one two weeks prior to admission. Overnight gastric secretion was 875 cc. with a free acid of 20 and a total acid of 50 units. Roentgenograms revealed a duodenal ulcer niche. After five weeks of medical treatment only partial relief was obtained and vagotomy was performed on April 8, 1947. Except for a pleural effusion, the postoperative course was uneventful and he was relieved of pain. Postoperative insulin hypoglycemia test demonstrated complete achlorhydria.

After 2½ symptom-free months he passed a tarry stool. Later his ulcer pain returned and he was readmitted to the hospital six months after vagotomy. At that time roentgen rays revealed some decrease in the size and activity of the ulcer. Overnight secretion was 250 cc. and the insulin test was equivocal.

Sixteen months after vagotomy he was again hospitalized for severe ulcer pain which simulated a perforation. Roentgen rays revealed an increase in the size of the

ulcer niche and the insulin test was now positive. High subtotal gastrectomy was performed on August 31, 1948. Three weeks later the patient complained of burning pain in the midepigastrium. Roentgen rays (Fig. 7), revealed an acute jejunal ulcer just distal to the stomal site.

Comment. Vagotomy, apparently complete, failed to prevent the development of a marginal ulcer after subsequent gastric resection.

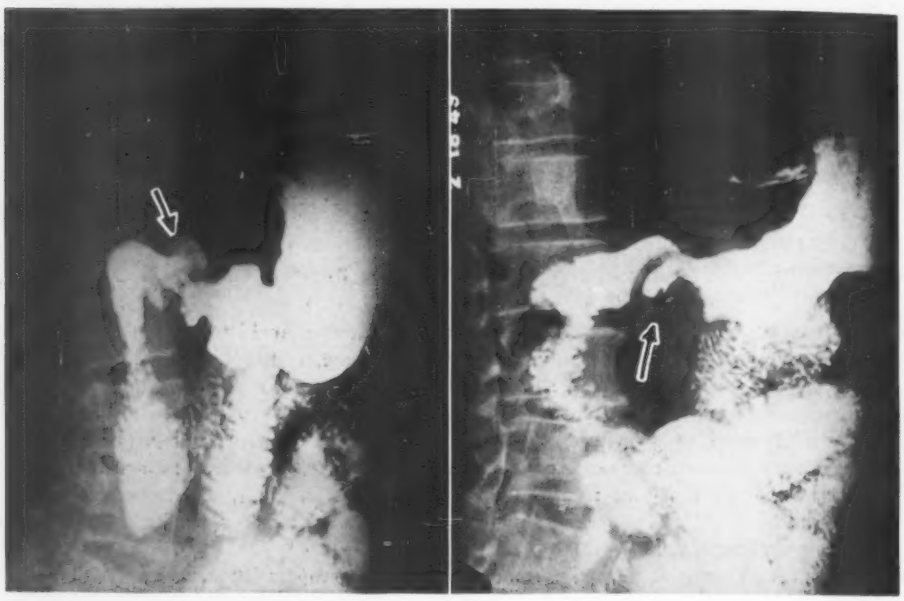


FIG. 4 FIG. 5

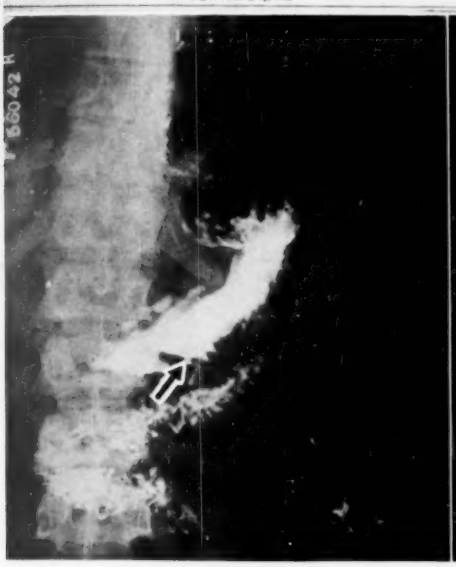
FIG. 4.—(Case 1). Two years after vagotomy showing active duodenal ulcer niche. Previous films had shown healing of the ulcer.

FIG. 5.—(Case 4). Twenty-seven months after vagotomy, roentgen ray reveals a large filling defect along the greater curvature of the stomach.

Case 17.—A 29-year-old male presented a history of ulcer pain for seven years including one episode of perforation 11 months before admission. Roentgen rays revealed an active duodenal ulcer. Overnight secretion was 250 cc. and acid values were normal. Transthoracic vagotomy was performed on May 28, 1947, with immediate pain relief. Insulin test was negative. Three months later he had recurrence of ulcer pain which became steadily worse and occasioned his admission to another Veterans' Hospital where, because of persistence of the ulcer and severe gastric retention, a gastroenterostomy was performed. Relief was only partial and 21 months after vagotomy he was again admitted to this hospital with his same preoperative symptoms. Roentgen rays revealed a deformed duodenal bulb. There was tenderness over the stomal site and an ulcer crater was demonstrated at the anastomosis. Insulin test was now positive. Dismantling of the gastroenterostomy and gastric resection were performed on March 30, 1949, 22 months after vagotomy. The resected specimen did not reveal a marginal ulcer despite the evidence on repeated films performed 10 days before (Fig. 8). The

FIG. 6

FIG. 7



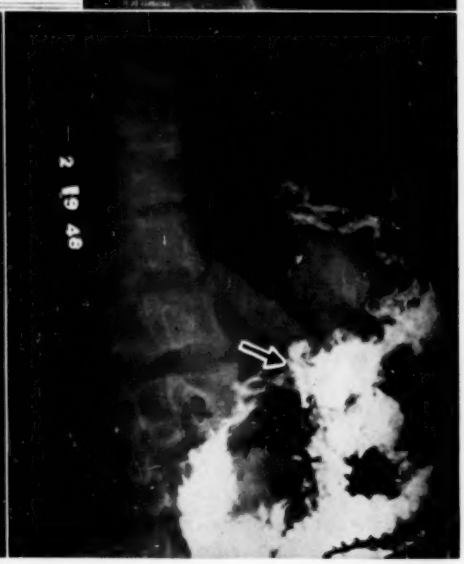


FIG. 8

FIG. 9

FIG. 6.—Resected stomach specimen (Case 4) revealing large lymphosarcoma of stomach. First portion of duodenum (on card) showed no evidence of ulcer.

FIG. 7.—(Case 14). Seventeen months after complete vagotomy and 22 days after gastric resection. Roentgen ray demonstrates an acute jejunal ulcer in the efferent limb of the anastomosis.

FIG. 8.—(Case 17). Twenty-one months after vagotomy, and 11 months after gastroenterostomy. Roentgen ray demonstrates a niche at the stomal margin. Findings observed on repeated films.

FIG. 9.—(Case 23). Six months after complete vagotomy. Roentgen ray demonstrates deformed duodenal bulb with a niche. Patient had relief of symptoms for four months.

postoperative course was complicated by a severe transfusion reaction and anuria. This was followed by marked ileus and leakage of the duodenal stump. Infection occurred in the operative wound which eviscerated on the ninth postoperative day. The patient died on the tenth postoperative day. Autopsy revealed a blowout of the duodenal stump and a diffuse peritonitis.

Comment. Despite apparently complete vagotomy and subsequent gastroenterostomy this patient went on to form a marginal ulcer. It is impossible to estimate the extent, if any, to which the vagotomy may have influenced the course of postoperative events which led up to the patient's death.

Case 22.—A 36-year-old white Turkish male presented a history of duodenal ulcer pain of three years' duration which became steadily worse despite medical treatment. There was clinical and laboratory evidence of cirrhosis of the liver. There was marked hyperchlorhydria with fasting specimens yielding free HCl, 100 units, and total acid, 120 units. Despite intensive medical therapy the patient continued to have pain and vomiting. Roentgen rays revealed an active duodenal ulcer. On August 20, 1947, transthoracic vagotomy was performed. The postoperative course was stormy as a result of marked atony and gastric retention, and an infection of the chest wound. Despite intensive therapy, including lavage, urecholine, and blood transfusions, the patient went downhill rapidly and presented symptoms and laboratory findings of severe liver damage. As a last resort to improve nutrition a gastroenterostomy was performed three months after vagotomy. He failed to improve, developed severe ascites and died in coma three months and 20 days after vagotomy. Autopsy was refused.

Comment. In retrospect this patient was a poor candidate for vagotomy. The nutritional loss occasioned by the marked postoperative atony was apparently sufficient to produce severe liver damage and death.

Case 23.—A 29-year-old white male gave a history of intractable duodenal ulcer pain of five years' duration. He had two massive hemorrhages at three years and at four months before admission. Roentgen rays revealed a duodenal ulcer niche. Overnight secretion was 1500 cc. with a free acid of 24 and a total acid of 43 units. On August 26, 1947, transthoracic vagotomy was performed with an uneventful postoperative course and relief of ulcer pain. Insulin test showed complete achlorhydria. He remained symptom-free for four months when his pain gradually returned to its preoperative intensity. After five months he was readmitted to the hospital where roentgen rays revealed an active ulcer with a niche (Fig. 9). Overnight secretion was 800 cc. Repeated insulin tests gave conflicting results, ranging from low, flat curves to high peaks of 320 units free acid and 350 units of total acid. Because of failure to respond, subtotal gastrectomy was performed on February 27, 1948, six months after vagotomy.

Comment. Here again the effect of vagotomy on symptoms and gastric secretions was a temporary one, with reversion to preoperative status after less than six months.

Case 26.—A 56-year-old white male presented a history of painful duodenal ulcer for 26 years, including a perforation six years previously, and numerous episodes of tarry stools over a period of 12 years. Roentgen rays repeatedly demonstrated an ulcer niche and no gastric retention. Transthoracic vagotomy was performed on October 3, 1947, with relief of symptoms for four months. Insulin (Hollander) test revealed a positive response indicating probable incomplete section of nerves. Patient did not desire further surgery. After four symptom-free months pain and bleeding recurred and have

been present intermittently since. Patient also carries a diagnosis of psychopathic personality.

Comment. In retrospect this patient should not have been chosen for vagotomy because of his psychiatric background and the difficulty of evaluating the results of the procedure. If the insulin test is a reliable criterion, it must be assumed that failure resulted because of incomplete section of the vagus nerves.

Case 27.—A 42-year-old white male gave a five-year history of duodenal ulcer with one episode of melena, and requiring repeated hospitalizations. One year before admission he had a perforation of the ulcer. Roentgen rays revealed an active duodenal ulcer with no obstruction. Overnight secretion was 1500 cc. with a free acid of 88 and a total acid of 109 units. Vagotomy was performed on October 21, 1947. Postoperatively he developed marked atonia and gastric retention. Urecholine 5 mg. t.i.d. was begun on the sixth postoperative day and later was increased to four times daily. Despite repeated gastric aspirations the stomach failed to regain tonus and the patient lost seven lbs. in the first 13 postoperative days. Gastric resection was performed on November 12, 1947, 22 days after vagotomy.

Comment. Perhaps this atonia would have responded if treated even longer. The weight loss, failure to regain tonus and severe gastric retention were factors which led to the decision for further surgical intervention.

Case 31.—A 55-year-old white male gave a history of ulcer pain for 30 years, including a perforation 24 years before admission and a five year history of repeated tarry stools. Roentgen rays revealed a duodenal ulcer. Acid studies were within normal limits. Transthoracic vagotomy was performed on November 19, 1947. There was relief of ulcer pain in the immediate postoperative period but he developed marked atony requiring repeated gastric aspirations and urecholine with partial relief. The insulin test was negative. Three months after operation the patient was readmitted because of persistent nausea, vomiting and weight loss. Roentgen rays revealed a markedly atonic stomach with 90 per cent retention of barium after four hours and 60 per cent retention after 24 hours. The duodenal cap could not be seen. Conservative treatment having failed, gastric resection was performed on March 3, 1948, three and one-half months after vagotomy with marked relief of symptoms. Five months later he noted recurrence of ulcer pain and tarry stools. Roentgen rays now revealed a marginal ulcer (Fig. 10).

Comment. Here vagotomy not only produced unrelenting atony, but also failed to protect the patient against development of a marginal ulcer after gastric resection.

Case 33.—A 21-year-old white male had a chief complaint of four years of duodenal ulcer pain. Symptoms were unrelieved after four weeks of strict medical regimen in the hospital. Transthoracic vagotomy on December 11, 1947, produced complete pain relief. Overnight secretion dropped to 325 cc. and the insulin test was negative on two occasions. He was symptom-free for six months when he noted gas, heartburn, fullness of the stomach and vomiting 2 to 5 times weekly. Partial relief was secured by diet and urecholine. Thirteen months postoperatively the ulcer pains recurred and gradually became more severe. Roentgen rays at 15 months showed an active ulcer with niche formation, and an enlarged, atonic stomach.

Comment. Because of the patient's age and chief symptoms of pain he was considered to be an ideal candidate for vagotomy. Pain relief was secured but only for 13 months, followed by reactivity of the ulcer.

Case 34.—A 42-year-old white male sustained a perforation of a duodenal ulcer five years before admission. After an asymptomatic period of three years he noted ulcer pain which became increasingly severe despite medical treatment. Shortly before admission he had severe hematemesis and melena. Overnight secretion was 625 cc. with a free acid of 100 and total acidity of 115 units. Roentgen rays revealed an active duodenal ulcer. Transthoracic vagotomy was performed on December 26, 1947, with relief of symptoms. Insulin test was negative postoperatively and overnight secretion was reduced to 125 cc. with five units free acid and 10 units of total acid. Following discharge he noted fullness in the epigastrium and abdominal distention. After five months, roentgen rays showed an inactive ulcer and the insulin test was equivocal. After ten months the ulcer pain recurred. At 14 months roentgen rays showed an active ulcer with niche formation and 50 per cent gastric retention after four hours. The insulin test was equivocal. There has been no further bleeding and patient is being continued on a medical regime.

Comment. Despite adequate vagotomy, pain recurred after ten months with reactivation of the duodenal ulcer.

Case 38.—A 29-year-old colored male gave a history of duodenal ulcer pain of five years' duration. He had had several previous hospital admissions for medical treatment. Overnight secretion was 450 cc. with free acid of 18 and total acid of 30 units. Roentgen rays revealed an active duodenal ulcer. On April 9, 1948, transthoracic vagotomy was performed with immediate relief of pain. Symptom relief was very transient and after several days he complained of epigastric pain, bloating and regurgitation. Roentgen rays on the eleventh postoperative day revealed a dilated atonic stomach with 75 per cent retention of barium after four hours. Overnight secretion on the sixteenth postoperative day was 270 cc. with no free acid and a total of 30 units. Insulin test showed complete achlorhydria. Despite gastric suction and urecholine, the patient continued to complain of pain and lost 10 lbs. in weight. On June 9, 1948, two months after vagotomy, subtotal gastrectomy was performed. Four weeks postoperatively the patient suddenly collapsed and died an hour later. Autopsy revealed a massive embolus in the right pulmonary artery.

Comment. This case is not considered a fatality from vagotomy since he had fully recovered from its effects save for the gastric atony.

Case 42.—A 28-year-old colored male gave a history of duodenal ulcer for five years with intractable pain and several episodes of bleeding. In October, 1947, gastric resection was performed at another hospital. He was relieved of pain for five months and then developed recurrence of pain associated with fullness, cramps, nausea, vomiting and hematemesis. Re-exploration of the abdomen was performed at another hospital in April, 1948, with lysis of intestinal adhesions. Although his obstruction was relieved, he continued to have epigastric and left upper quadrant pain partially relieved by alkalis and milk. The pain became worse and he was admitted to this hospital July 7, 1948. A G. I. series revealed evidence of a marginal ulcer. After an unsatisfactory trial of a careful medical regime, transthoracic vagotomy was performed on September 15, 1948. Postoperative course was uneventful and patient was relieved of pain. Insulin test postoperatively was negative. Three months later his ulcer pain recurred with only partial relief by alkalis or food. Nausea and vomiting were subsequently experi-

enced and he sought readmission to the hospital. Marked tenderness was noted in the left epigastrium and roentgen rays revealed marked spasm of the efferent jejunal loop, although an ulcer crater could not be visualized. Insulin test was equivocal. Gastroscopy did not reveal the presence of a marginal ulcer.

Comment. This case was considered a failure because of complete recurrence of preoperative symptoms and demonstrable evidence of persistent abnormality of the efferent jejunal loop.

Case 44.—A 47-year-old white male had a gastroenterostomy performed for obstructive duodenal ulcer in 1939. He was relieved until 1946, when he had left upper abdominal and umbilical pain, vomiting and a 30-pound weight loss. Roentgen rays revealed narrowing of the efferent loop with two ulcer craters, and no gastric retention. Transthoracic vagotomy was performed on January 22, 1947. The early postoperative course was uneventful but on the tenth postoperative day there was evidence of obstruction and the patient vomited repeatedly. Roentgen rays on the thirteenth postoperative day revealed a tremendous dilatation of the stomach (Fig. 11). Treatment with continuous gastric suction, prostigmine, and intravenous alimentation produced only partial relief. The patient tolerated a soft diet for two months but failed to gain weight and continued to have severe gastric atony. Insulin test revealed evidence of complete vagus nerve section. A two weeks course of urecholine (10 mg. t.i.d. before meals) did not influence the obstruction favorably and on April 9, 1947, two and one-half months following vagotomy, the gastroenterostomy was dismantled, the involved jejunal segment resected and gastric resection performed. The specimen revealed a stenosis of the pylorus, narrowing of the efferent jejunal loop, and an active stomal ulcer. Six months later roentgen rays of the stomach revealed a good stoma, no ulcer and no retention.

Comment. In this case an apparently complete vagotomy failed to heal a marginal jejunal ulcer after two and one-half months. The procedure apparently converted a potential stomal obstruction into a most extreme retention which was not favorably influenced by conservative therapy.

Case 46.—A 56-year-old white male gave a history of painful duodenal ulcer with vomiting for 28 years. In January, 1947, a G. I. series revealed almost complete pyloric obstruction with deformity of the duodenal bulb. On February 4, 1947, a posterior gastroenterostomy was performed with marked relief of symptoms. He was well for four months and then developed epigastric pain with intermittent vomiting. Roentgen rays revealed a large ulcer crater just distal to the anastomatic stoma. On July 7, 1947, transthoracic vagotomy was performed with complete relief of symptoms. Insulin test was negative. Nine months postoperatively he noted left upper quadrant pain relieved by food or alkalis. Roentgen rays 14 months after vagotomy revealed a large ulcer crater in the proximal portion of the efferent jejunal loop (Fig. 12). The patient has continued to have pain, with intermittent tarry stools, until the time of this report, 20 months after vagotomy.

Comment. Despite apparently complete nerve section, this patient failed to gain more than five months of symptom relief and demonstrated either persistence or reactivation of the marginal ulcer.

Case 48.—A 46-year-old merchant seaman gave a history of duodenal ulcer of three years' duration. Two years before admission a subtotal gastrectomy was performed at another hospital. Subsequently he underwent four laparotomies presumably for intestinal obstruction. He entered this hospital with a two-day history of severe upper abdominal pain and vomiting.

FIG. 10

FIG. 11

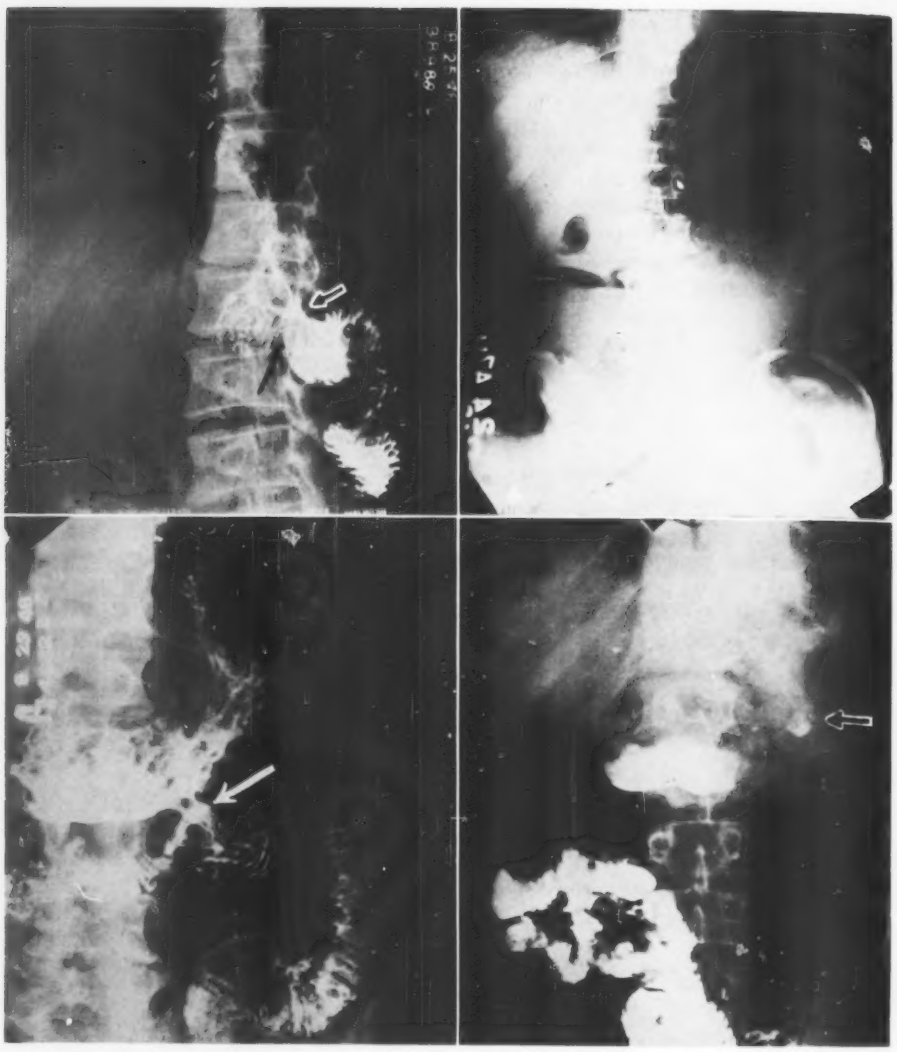


FIG. 12

FIG. 13

FIG. 10.—(Case 31). Nine months after vagotomy and 5½ months after gastric resection for duodenal ulcer. Roentgen rays demonstrate an acute ulcer niche in the efferent limb of the jejunum.

FIG. 11.—(Case 44). Thirteen days after vagotomy. Roentgen ray reveals tremendous dilatation of the stomach which is filled with fluid and air and occupies two-thirds of the abdominal cavity.

FIG. 12.—(Case 46). Fourteen months after vagotomy for marginal ulcer. This demonstrates large persistent ulcer crater in the proximal portion of the efferent jejunal loop.

FIG. 13.—(Case 45). Eleven months after vagotomy for post-gastroenterostomy stomal ulcer. Despite complete symptom relief there is a persistent ulcer niche and barium retention in the stomach after four hours.

Laparotomy with lysis of intestinal adhesions was performed on September 26, 1947. Relief was temporary and a second exploration was done nine days later with jejuno-jejunostomy to bypass an obstructed loop. The patient's pain continued and now roentgen rays revealed a large stomal ulcer crater without gastric retention. Overnight secretion was 520 cc. with no free acid but 75 units of total acid. Because of persistence of pain and vomiting, and failure of previously performed laparotomies to relieve the symptoms, it was felt that the stomal ulcer was responsible.

Accordingly, on November 4, 1947, transthoracic vagotomy was performed with immediate and dramatic relief of pain. The patient became uncooperative and left the hospital before further secretion studies could be performed. Since discharge he has had recurrence of abdominal pain and persistence of the stomal ulcer.

Comment. This case was not an ideal selection for vagotomy because of the difficulty of evaluating postoperative symptoms. However, the dramatic relief of pain after vagotomy, after failure of many previous operations, indicates that the stomal ulcer played a major role in the clinical picture.

SUMMARY

We have not been able to confirm the encouraging reports of other investigators with regard to the effectiveness of vagotomy in the treatment of duodenal and marginal ulcer. Fifty carefully selected cases with intractable pain, and without obstruction, were subjected to transthoracic vagotomy without any associated surgical procedure to obscure the final result. There was one death in the series. In the early postoperative period we were able to confirm previous reports with regard to nearly uniform relief of symptoms, diminution of secretory volume and acidity and a high incidence of gastric atonia.

One hundred per cent follow-up was obtained over a period of six to 30 months postoperatively, an average of 18 months. Rehospitalization was accomplished on nearly all cases from one to four times for careful symptom analysis, roentgenograms and secretion studies. Symptomatic results were excellent in 18 per cent, good in 36 per cent, fair in 12 per cent, and failure in 34 per cent. There were five failures (10 per cent) in the early postoperative period due to unrelenting atony which necessitated further surgical intervention. The remaining 24 per cent were failures because of recurrence of preoperative symptoms during the follow-up period. Roentgen ray healing of the ulcer was noted in 42 per cent of the cases but 38 per cent showed either persistence or recurrence of active ulcer during the follow-up period (three to 30 months). Roentgen ray evidence of gastric atony, enlargement and retention, previously reported as a transient phenomenon was observed in 42 per cent of the cases throughout the follow-up period.

In failure cases, the relief of pain afforded by vagotomy was temporary, lasting from three to 24 months. Nine of the 17 failures required subsequent gastric resection or gastroenterostomy. Three of these cases later developed marginal ulcers despite apparently complete nerve section. There was no evidence that vagotomy favorably influenced symptoms of bleeding which was noted in 22 per cent of cases in the follow-up period.

Although the period of follow-up observation of these cases is somewhat short to draw final conclusions, nevertheless, the relatively large percentage of unsatisfactory results noted up to the present time is very significant and clearly indicates that the procedure has serious limitations in the treatment of peptic ulcer. In reconciling the poor results noted in this series with the favorable reports of other observers it must be remembered that frequently the latter are based upon vagotomy in combination with gastroenterostomy. It is commonly recognized that gastroenterostomy alone gives generally excellent early results but that the duration of beneficial effects is inversely proportional to the length of the follow-up period. Only after observations have been made over many years will we know whether or not the combination of vagotomy with gastro-enterostomy or other surgical procedures is a rational one.

According to our data a patient who is subjected to vagotomy has one chance in five of securing complete relief; two chances in three of being benefited to some extent; and one chance in three of failure—all within an average of 18 months postoperatively. For this rather dubious benefit he must accept a small but nevertheless significant mortality risk and the unhappy prospect that his continued freedom from ulcer symptoms is by no means assured. Half the time he must also pay an additional premium in the form of persistent symptoms of gastric atony which not infrequently may be more disabling than the original ulcer.

On the whole, we feel that vagotomy, even in carefully selected cases, has not proved successful in a sufficient number of cases to justify its routine use. Despite the lower operative mortality, failures are too frequent and morbidity too serious after vagotomy to justify its replacement of other proved more effective methods of surgical treatment.

CONCLUSIONS

1. Careful follow-up studies are reported in 50 selected cases of non-obstructed duodenal or marginal ulcer treated by transthoracic vagotomy without other associated surgical procedures.

2. Failures were observed in 34 per cent of cases after an average follow-up period of 18 months.

3. Previous reports of other investigators concerning the long-term effects of vagotomy on symptom relief, ulcer healing, gastric secretion, and secondary symptoms have not been confirmed.

4. There are serious limitations of vagotomy in the treatment of duodenal and marginal ulcer.

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SOME REFLECTIONS ON SURGICAL PRINCIPLES IN TREATING CANCER OF THE COLON AND RECTUM

BASED ON AN ANALYSIS OF 70 PATIENTS*

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THE STORY OF THE surgical treatment of carcinoma of the large bowel is somewhat like a three-act drama in which the scene and action in the last act are similar to the first. To be sure, the characters and the results are quite different. Because of the almost complete revolution in the cycle, it might be of interest to review our own series of malignant lesions of the large bowel and rectum, and to examine the data and results in an effort to determine what lessons might be learned from such constant change.

Back in the "gay-nineties" when one of us (U. M.) first became interested in intestinal surgery, resection of the colon with an open end-to-end anastomosis was in vogue. True, not many resections had been performed, yet Billroth[1] was able to report a series of 17 cases in 1889 with a 60 per cent mortality. During residency at Touro Infirmary, in 1898 and 1899, not one elective resection of the colon or rectum was observed. In 1903, Mickulicz[2] reported 24 cases in the Boston Medical and Surgical Journal with a mortality of only 16.6 per cent, having utilized a multiple-stage exteriorization procedure developed by Block[3] on the continent and Paul[4] of Liverpool. As a result of these publications most surgeons adopted staged operations as the procedure of choice for malignant lesions in all levels of the colon except the rectum.

The first successful extirpation of the rectum had been performed by Lisfranc[5] in 1826. He used the perineal approach, which Allingham[6] was one of the first to modify, by leaving the external sphincter in situ. Because of tension it was rarely possible to attach the remaining rectum to this muscle, and the wounds healed poorly. Despite the fact that such operations were considered "barbarism . . . and part of the surgery of a by-gone age,"[7] many fine surgeons attacked the problem with vigor. In an epochal paper, Kraske[8] advised removal of a portion of the sacrum. This was the first effort towards a more radical approach. At first Kraske was content to suture only the anterior walls of the remaining rectum, but later advised a complete anastomosis. If enough slack could be attained, Hochenegg[9] pulled the proximal portion down to the anal skin or, if this was impossible, he created a sacral anus.

Because of technical difficulties, Czerny,[10] in 1883, was compelled to do a combined abdomino-perineal resection. Later, Maunsell[11] and Quenu[12] advocated the combined method as an elective procedure. Fifty years ago, Tuttle[13] stated, in words which sound as if they might have been written yesterday,

* Submitted for publication May, 1949.

"Where the tumor is limited to that portion of the intestinal tract entirely surrounded by peritoneum . . . abdominal resection is undoubtedly superior to all others . . . and can be quickly executed by [aseptic methods]. Where the tumor is well below the promontory of the sacrum, however, in that portion of the gut only partially covered by peritoneum, complete removal by this route alone is attended with many difficulties." Mann,[14] of Buffalo, advocated anterior resection and anastomosis for all lesions of the rectum proximal to the distal two inches in an article published in 1901, the same year that he tried to save the assassinated McKinley.

Miles,[15] in 1908, presented reasons for the radical removal of lower sigmoid, rectum and anus which were so convincing that the debate of anterior resection versus posterior resection was almost silenced. Babcock[16] and Bacon,[17] however, have continued to fight for preservation of the sphincters and perineal anus, and Horsley[18] and Dixon[19] for anterior resection.

In 1928, Rankin[20] modified the exteriorization operation with the introduction of obstructive resection accomplished by a special clamp. Several years later he reported 31 cases with a mortality of 3 per cent.[21] In the meantime proponents of a one-stage operation, because of the extremely high incidence of infection, experimented with various closed methods of anastomosis to achieve asepsis. O'Hara[22] and Schoemaker[23] devised special clamps, Martel,[24] an ingenious steel bow, and Parker and Kerr[25] the basting stitch. In 1940, Kerr[26] stated that over 40 methods of aseptic anastomosis had been described. Improved clamps devised by Furniss,[27] Stone[28] and Wangensteen,[29] among others, have given further impetus to the closed method. There is unquestionably a decided trend, at the present time, towards the more frequent use of aseptic primary anastomosis (Gibbon[30]). Nevertheless, a number of eminent authorities still prefer extraperitoneal obstructive resection, particularly in the distal colon, as they have found that they obtain a lower mortality with two sittings.

A further debatable point has been the use of proximal decompression. Wilkie,[31] Whipple,[32] Cheever,[33] Dixon,[34] and others favored proximal cecostomy or colostomy. Stone and McLanahan,[35] Wangensteen,[36] and Waugh[37] are among those who oppose it in the non-obstructed case.

The introduction of intestinal chemotherapy by Firor and Jonas[38] has added further sub-divisions to the various camps of adherents of one or another method. Finally, Meyer[39] has recently endorsed one-stage open anastomosis just as did Reybard[40] and Kohler,[41] who started colon resection for cancer; and the stage is set just about where it was 50 years ago when the senior author first started his surgical career.

Thus, we now have those who advocate staged procedures, as well as advocates of a one-stage operation; those who believe in open anastomosis and those who prefer a closed one; those who use complemental decompression, and those who do not. One school is intent on preservation of the perineal anus, either by "pull-through" operations or anterior resection, while another

will have nothing to do with such conservatism. And there is the group of surgeons who prefer one of the above plans but do not use preoperative chemotherapy, and the group who do. Certainly such division of opinion is confusing to the younger surgeon and makes it extremely difficult for him to select the optimum plan for his patient.

While it is obvious that no one method is best for all cases, we are convinced that adherence to certain fundamental principles will enable the surgeon to choose the method best suited to the majority of his patients. First and foremost is earlier diagnosis and surgical intervention; Second, is radical extirpation of the lesion and its lymphatic pathways; Third, is adequate physiologic and pharmacologic preparation of the patient; Fourth, is complemental proximal decompression to avoid distention and tension on the suture line; Fifth, is simplicity and adaptability of technic.

These fundamentals are reviewed in the light of our experience with 70 consecutive operations on the colon and rectum done during the past 16 years, all from the surgical service at Touro Infirmary.

1. *Earlier Diagnosis.* The rise in resectability rate and lowering of operative mortality leave little to be gained by advances in technic or management alone. The only hope for an improvement in curability lies in extending diagnostic measures. Consequently, we must adopt the obvious principle of earlier recognition as the corner-stone of any group of rules.

Since many of the symptoms given in many texts are of little actual value in making an early diagnosis, attention must be directed towards earlier abnormalities of function. These include recurrent bouts of vague abdominal distress, darkening in color or specks of blood in or on the stools, and gradually changing bowel habits. In these days of oil and radio-ballyhooed "nature remedies," constipation often passes unnoticed, but the use of steadily increasing amounts of laxatives by a patient may be a valuable lead. With such hints a complete physical examination is indicated. This must include sigmoidoscopy and roentgen ray studies. It should be remembered that few *rectal* lesions can be visualized by roentgenogram, but approximately 70 per cent of rectal cancers can be felt with the examining finger while almost 75 per cent of all large bowel cancers can be seen with the sigmoidoscope. Periodic physical examination in the absence of a suggestive history does not seem to be a practical approach. Given an early diagnosis, the percentage of patients with initial signs of obstruction and, thus, higher operative mortality and lessened curability, will be decreased. In addition, the number of cases with extension through the serosa, distal lymphatic metastases, and blood vessel spread will be minimized.

2. *Radical Operation.* One of the major objections to exteriorization procedures is the inability to resect widely the areas of lymphatic drainage at the root of the mesentery. The danger of local implants was largely abolished by Rankin's modification. Nevertheless, multiple procedures entail multiple risks, a higher incidence of complications, and prolonged hospitalization.

The investigations of Jamieson and Dobson[42] on lymphatic spread have been extended by Dukes and Gabriel,[43] Gilchrist and David,[44] and Coller and his workers.[45] The number of nodes involved were found to be much greater than previously suspected. Retrograde extension occurred rarely, but blood vessel invasion was found in about 15 per cent of cases. Might it not be that the higher curability rate for right sided lesions is related to the radical hemicolectomy performed, in contradistinction to the more limited resections on the left side?

Consideration of blood supply has been emphasized by Steward and Rankin,[46] and Singleton.[47] Inconstancy in vascular anastomoses between the terminal branches of both superior and inferior mesenteric arteries must be understood by the surgeon, as viability of remaining bowel must not be jeopardized by any weak links in collateral blood supply. On the other hand, the critical point of Sudek has been de-emphasized. Observation of small vessel pulsation, reflex muscle contractility and color of the bowel will guide us in estimating adequacy of circulation. Utilizing these aids, a radical operation with immediate anastomosis is feasible.

3. *Adequate Preparation.* Proper cleansing of the bowel and elimination of distention have been emphasized for many years. Advances in physiology and pharmacology have enabled us much more adequately to prepare the patient. Replacement of protein and weight loss, fluid and vitamin deficiencies, and diminished blood volume are recent advances which have added considerably to lowering of the mortality. Improvements in anesthesia and management of shock are further contributions to the procedure itself. The use of whole blood to restore a normal blood volume is of utmost importance.

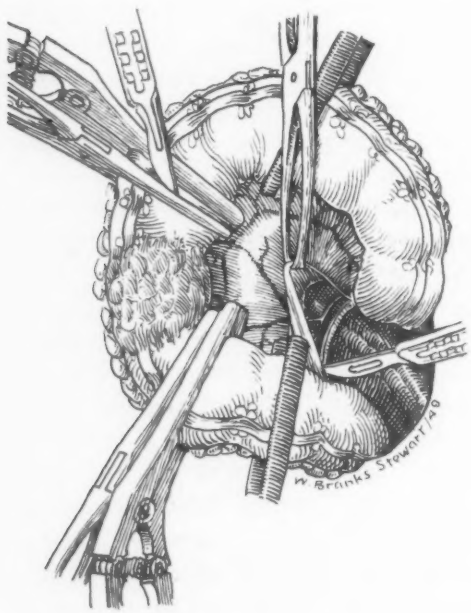
Another significant benefaction, in our opinion, is the employment of intestinal chemotherapy to minimize infection. Because of well intentioned aims to emphasize other prominent factors, some surgeons have belittled this outstanding advance and others have even declined to use such drugs, but they appear to be a minority. The improvement in our mortality figures since the addition of this measure is noteworthy, and the results of numerous clinical and laboratory experiments only serve to emphasize the value of chemoprophylaxis in the preparation of the patient.

4. *Complemental Decompression.* This principle has received much attention and, recently, Graham[48] has found that approximately 30 per cent of a selected group of surgeons questioned continue to use it. We readily admit that this is one of the least important measures in the non-obstructed patient, and much of its value has been obviated by tube decompression. However, we still prefer to use such a safety valve, mainly to eliminate pressure on the suture line. There is also added comfort to the patient when peristalsis proximal to the resected area begins, and the artificial vent allows elimination of gaseous distention. We have rarely had complications arising from employment of this measure which was so strongly advocated by C. H. Mayo.

5. *Technic.* It should be emphasized that we must be open-minded in the selection of the particular type of operation indicated in the individual

patient. Of course, earlier diagnosis means earlier operation, thus avoiding those conditions which may invalidate primary resection with immediate anastomosis. Our success will depend on operation before obstruction, perforation or gross infection have occurred, all of which may require proximal drainage or deviation of fecal stream before any definitive surgery can be attempted.

If a definitive procedure is feasible, we believe that the simplest and most direct one which allows achievement of the aforementioned principles will give the best results. Hence, a one-stage resection with end-to-end anastomosis is advocated. Because closed types of anastomosis entail additional steps, we



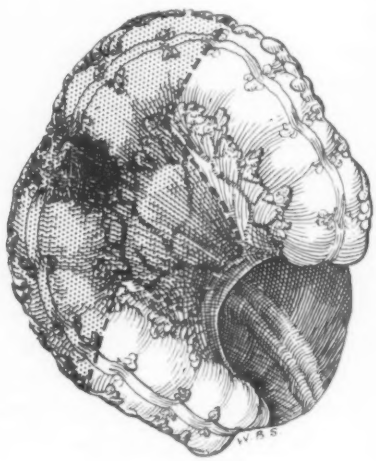


FIG. 1 FIG. 2

FIG. 1.—Excision of bowel between Payr clamps. Mobilization by incising avascular "Monk's white-line."

FIG. 2.—"U"-shaped resection of mesentery rather than usual "V". Angulation towards anti-mesenteric border as described by Madelung.

prefer open anastomosis. The preoperative use of a non-absorbable sulfonamide makes this procedure relatively safe.

Some of the more significant technical details of a sigmoid resection are discussed: The abdomen is entered through a left rectus-splitting incision with the patient in slight Trendelenburg position. Spinal anesthesia is preferred. Exploration is done and, unless there is evidence of widespread metastasis, resection is attempted. The peritoneum is incised at its reflection from the mesentery (Monk's white line) (Fig. 1). After the major vessels are visualized, they are clamped, cut and ligated. If the lesion is a low-lying one, steady

traction on the pelvic colon at this stage frequently gives added exposure. The mesentery of the bowel is then cut, not in the usual "V" manner, but in a broad "U," to and including its root, thereby enabling the maximum of lymph bearing tissue to be removed (Fig. 2).

Rubber-shod clamps are placed on the near and far sides of the tumor to interrupt any fecal flow. As much bowel as possible on both sides of the lesion

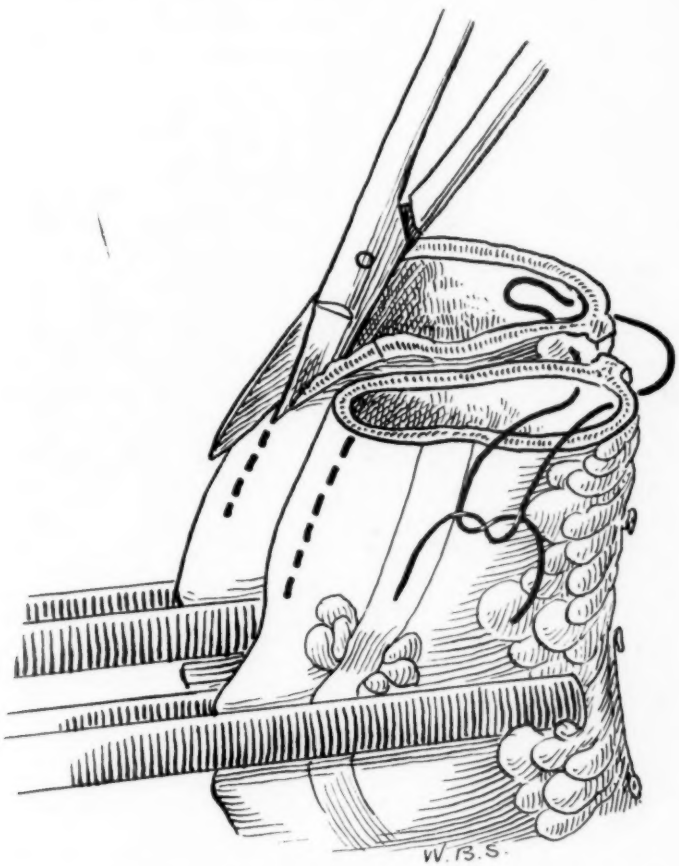


FIG. 3.—Utilization of Cheatle's slit on anti-mesenteric border to increase and equalize lumen.

is sacrificed, consideration being given to the fact that the two ends must be brought together without tension. With Allis clamps marking the site of resection, thin-bladed Payr clamps are placed at an angle of approximately 60° to the mesenteric border, as initially suggested by Madelung.[49] The actual portion to be excised is clamped with Kocher forceps and the colon severed with a sharp knife. We do not like the actual cautery. Heating clamps with the cautery may be responsible for transmission of excess heat to adjacent bowel with subsequent slough. We do appease surgical sensibilities by wiping

the open ends with an iodine sponge. The Payr clamps are removed and the crushed tissue trimmed off. The viability of these margins is then checked, and if there is doubt as to adequate blood supply more bowel must be resected.

Because of the inequality in the diameter of the two ends of the intestine,

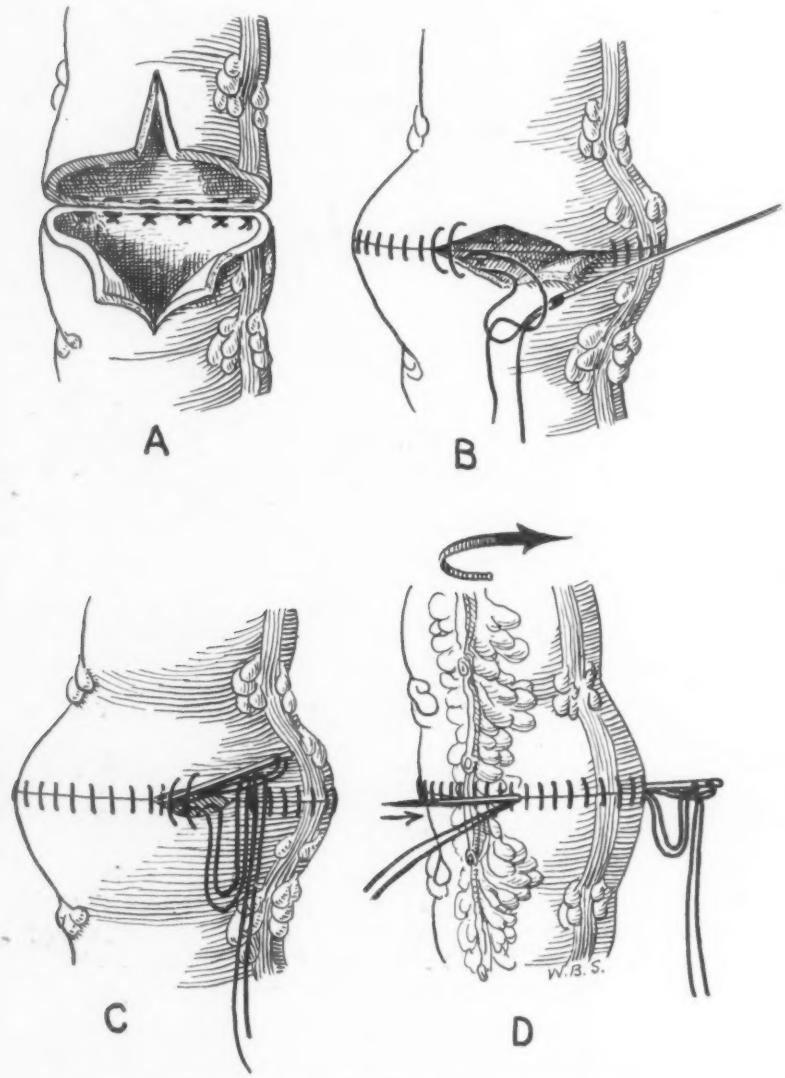


FIG. 4.—A and B. Progressive steps in the placement of Connell's suture. C and D. The only new feature of this suture as stated by Connell was the method, as shown here, of securing the final suture so that all knots are on the inside.

the smaller end or both are usually split for a varying distance on the antimesenteric border, described first by Cheatle.[50] (Fig. 3.) End-to-end anastomosis is then accomplished by means of a single layer of interrupted Connell[51]

"U" sutures with all knots tied in the lumen (Fig. 4). Fine silk is used on a straight intestinal needle. If placed carefully and with attention to detail, one row of sutures provides a perfectly adequate hemostatic and water-tight closure (Fig. 5). For added precaution the ends of adjacent appendices epiploicae are

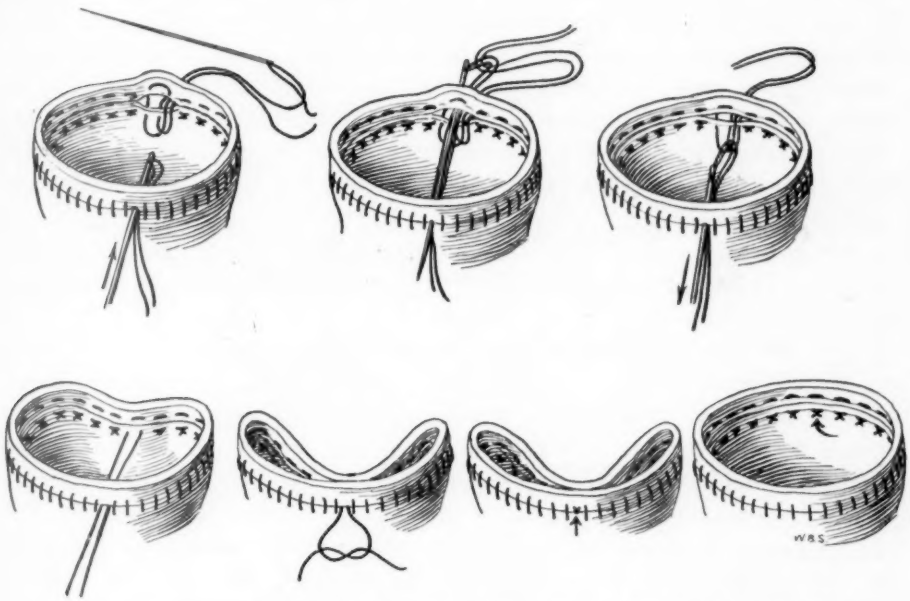


FIG. 5.—Diagrammatic sequence of securing last suture so that knot though tied and cut on outside remains in interior.

tacked over the suture line. One row of sutures obviously produces less diaphragm than several rows (Fig. 6). Single-layer closure has been used in 26 consecutive cases (including three colotomies for removal of malignant polyps) during the past eight years without an operative death.

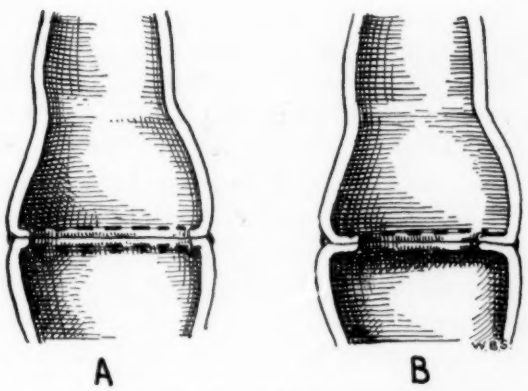


FIG. 6.—A. Result attained by use of one row of sutures.

B. Formation of partial diaphragm with use of additional suture layers.

Reperitonealization is accomplished, after which a Stamm-type colostomy using a Pezzar catheter is done several inches proximal to the suture line. The end of the catheter is passed through an opening made in the omentum and out the upper margin of the incision, or sometimes through a small stab wound in the flank to humor the residents.

The suture line is then inspected and sulfanilamide crystals sprinkled over the area. The omentum is replaced and the wound closed in layers.

If there has been no excessive weight loss and the abdominal wall appears strong, the peritoneum is closed with continuous catgut, and the fascia with interrupted silk. But if the various layers seem to be unduly pale or attenuated, or there is a history of marked wasting, the peritoneum and fascia are closed as a single layer employing Whipple's[52] far-and-near figure-of-eight stitch. Formerly, silk was used for this suture, but because of the large bites of tissue taken, we now use medium chromic catgut. If the fatty layer is very thick, Babcock wire-retention sutures through the fascia are emplaced and fastened with Davey buttons. No drains are used. If there has been unexpected spillage, the peritoneum alone is closed and the remainder of the wound packed with dry gauze.[53] Secondary closure can usually be performed four to five days later and, at that time, the fascia and skin may be closed with interrupted sutures.

Postoperative Measures. Five hundred cubic centimeters of blood is usually given during the procedure and, postoperatively, as indicated. Penicillin is routinely given for four to five days. Fluids are given sparingly by mouth the first day, and all liquids, except milk, freely on the second day. Sufficient intravenous fluids are given to insure a urinary output of 1000 to 1500 c.c., depending on the patient's age and cardio-renal status. Less saline has been given in recent years although we have always preferred to keep our patients slightly more on the "dry" than on the "wet" side. If it is necessary to check the salt balance of the patient, the urinary chloride output can be accurately and easily estimated, as emphasized by Marriott.[54]

The patient is encouraged to sit up early. Frequent changes in position, leg exercises, and stimulation of deep breathing with 10 per cent carbon dioxide are useful in the postoperative period. There seems to be a tendency on the part of many present-day surgeons to overtreat his patients. We prefer to treat complications as, and if, they arise, and for that reason do not advocate such extreme measures as prophylactic femoral vein ligation, and so forth. The revival of simplicity in surgery is a welcome sign.[55]

Extent of Operation. A right hemi-colectomy is now the standard procedure for lesions of the right half of the colon. Wide resection with end-to-end anastomosis is, likewise, generally accepted for the transverse colon. The splenic flexure offers special problems.[56] In addition to being a greater diagnostic problem, its high and fixed position may present technical difficulties. Obstruction is not uncommon, and a proximal decompression of some type may be necessary.

For the left side of the colon, the closer the lesion approaches the peritoneal reflection, or "clinical recto-sigmoid junction," the more vigorous the debate becomes as to the proper operation. As a result of the centrifugal lymphatic drainage described by Miles and Lockhart-Mummery, the older school of surgeons used a higher dividing line to make the choice between local resection

and the more radical abdomino-perineal operation. The more recent studies have all emphasized the predominant upward spread from the rectosigmoid and most of the rectum. Nevertheless, these same investigators (Gabriel,[57] Rankin,[58] David[59]) still strongly advocate the principles propounded by Miles.

It is our opinion that the peritoneal reflection is the lowermost limit for abdominal resection in the majority of cases, and for lesions below this line we prefer the combined operation. Nevertheless, the trend at present is un-

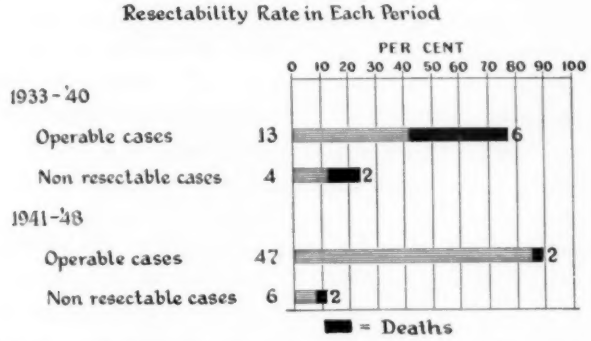


FIG. 7.—Graphic representation of improvement in resectability and mortality in the two eight-year periods.

TABLE I.—*Types of Operations Performed in 70 Consecutive Cases.*

		1933 – 1941		1941 – 1948	
Rectal Cases 25		Cases	Deaths	Cases	Deaths
Abdomino-perineal....	16	3	1	13	1
Post. resection.....	6	1	0	5	1
Removal of polyp.....	1	0	0	1	0
Non resectable.....	2				
Colon Cases 45					
Primary E. E anast....	29	6	3	23	0
2 stage Mikulicz.....	5	3	2	2	1
Colotomy (polyp).....	3	0	0	3	0
Non-resectable.....	8				

doubtedly toward anterior resection for lesions extending down into the upper portion of the rectum, and the results obtained by Dixon,[60] Wangensteen,[36] Best[61] and others must be given careful attention.

While posterior resection, with excision of coccyx and part of sacrum, is done on occasion, we believe its use is strictly limited to a small group of aged and feeble patients who do not appear able to withstand a more formidable operation, or who show evidence of distant metastases.

Analysis of Cases. A new era began in 1941 with the introduction of intestinal antibiotics. The lead of Firor and Jonas was quickly followed up on our service, and the various sulfonamides have been used ever since. For this

reason, we have divided this series of cases in two groups: from 1941 to 1949, and a comparable eight-year period prior to 1941 (Fig. 7 and Table I). The earlier group includes 17 cases, 13 of which were resected. There were eight deaths or a mortality of 47 per cent. We were able to obtain autopsies on all of these, and it was found that six of the deaths were due to peritonitis, one resulted from pulmonary embolism and one from a perforated duodenal ulcer. There are 53 patients in the more recent period, of whom 47 were resectable. There were two deaths in this group, or a mortality of 4.2 per cent. Two of the six non-resectable cases died. One of the patients died after four months from generalized carcinomatosis, and another in one month from a pulmonary embolus, one from shock and anuria, and only one from peritonitis. This last patient was admitted with acute obstruction and, on exploration, a perforation was found. There is a decided reduction in mortality in the latter group. Undoubtedly, a number of factors are responsible, but we agree with Pemberton[62] that the major one is the assistance given by chemotherapy.

The resectability rate in the earlier period was 75 per cent as compared to 89 per cent in the later one. The mortality is understandably much higher in the non-resectable cases—50 per cent in the first group and 33 per cent in the second. These patients all had acute intestinal obstruction on admission and required immediate operative decompression. Nothing further could be accomplished for them.

There is nothing remarkable in the age or sex incidence. There are more females than males—and women also predominate in the younger age groups. Most of the patients were in the sixth decade. The average age of the males was 64 years and of the females, 61.5 years. Three patients were in their eighties and, fortunately, all three survived resection.

Almost three-fourths of the large bowel lesions were located in the sigmoid colon, and the remainder equally divided between the ascending and transverse colon. There were 25 rectal lesions, which is a lower percentage than usual (Fig. 8). The concentration of colon and rectum tumors in the recto-sigmoid region is cogent reason for the continuing debate on the optimum approach to such lesions.

Six patients had malignant polyps, two of which were associated with carcinomas of the sigmoid colon. One patient had multiple polyposis with malignant transformation. There was one double malignancy of the rectum and colon with neoplastic infiltration of a complicating ileo-colic fistula. A block resection of colon and ileum, end-to-end anastomosis of ileum, and abdomino-perineal resection was done on this 70-year-old man and, when checked recently, he was well and working.

DISCUSSION

It has been said that if cancer of the bowel started like a toothache we could expect many cures. Unfortunately, malignancies of the intestinal tract have no hall-marks for early diagnosis. Being suspicious of minor signs or symptoms

should make for earlier recognition before metastasis has occurred. Thus, more patients will be seen who are not yet the victims of anemia, toxemia, partial obstruction or the other complications which contribute to the discouraging chapter on cancer of the colon and rectum.

Large series of studies have shown that one-third to one-half of all malignant lesions of the large bowel and rectum are within reach of the finger (70 per cent of rectal cancers). About three-fourths of all such malignancies are within reach of a 10 in. proctoscope. A finger or look in the rectum gives more information, frequently, than a thermometer in the mouth.

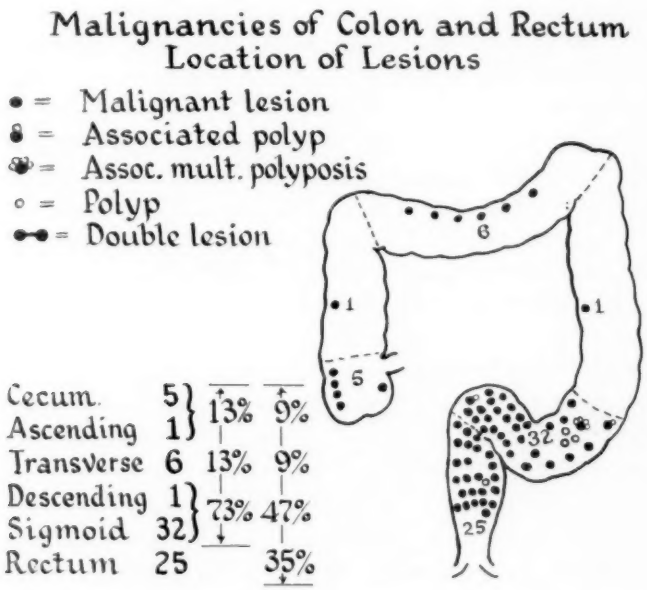


FIG. 8.—Distribution of lesions. Note that most occur in region of recto-sigmoid.

It is well to recall that the operation of Miles was the turning point in the successful management of cancer of the gastro-intestinal tract, and it was only after his publications that we began to think in terms of curability. Before 1907 recurrences were well over 90 per cent. Only the early low neoplasms offered any hope at all. With improvements in technic, more thorough preparation of the patient, chemoprophylaxis, blood transfusions and improved anesthesia, the operative mortality has been reduced to safer limits with a five-year curability of 50 per cent or more. An important point in lowering the operative mortality of the combined procedure, in our opinion, was recognition of the fact that it is not necessary to turn the patient on his face for the perineal dissection.

It is obvious that wide resection with restoration of the lumen is the operation of choice in the right half of the colon as well as the transverse colon.

This holds true for the left colon down to the distal sigmoid. The closer the lesion approaches the peritoneal reflection, the greater the controversy becomes as to the indications for the Miles procedure in its entirety, or whether a local resection with immediate anastomosis does not serve an adequate purpose. The permanent colostomy is still the main objection offered by patients to the radical operation. If, however, the patient can be convinced that he has a better chance of living with a colostomy than with an incompletely removed cancer, he will naturally choose the colostomy.

We believe that it is necessary to weigh many factors in making this decision. Some patients are extremely poor candidates for any type of artificial anus, because of age, feebleness, lack of aid, mental make-up, and so forth. This group should be eliminated for consideration of colostomy, if possible. It must be realized that high (sacral) implantation of the rectum is no more satisfactory than an abdominal colostomy. The so-called "posterior resection with preservation of sphincter control" has been unsatisfactory, in that a good anastomosis is not often possible, and slow healing due to poor blood supply and infection is common. Some of the more recently suggested "pull-through" operations may be successful so far as recovery is concerned, but unless the lesion is very early and limited to the upper half of the rectum, the disruption of rectoanal reflexes diminishes sphincteric continence to the point where it is of little practical value (Gaston[63]), and such operations cannot be recommended.

We may have been influenced in the past by the statements of the pathologists that the lymphatic spread was "upward, outward and downward." By studying those patients who have had recurrences, as well as the recent investigations on lymphatic drainage, we are forced to wonder about downward spread. Consequently, for sigmoid lesions down to the peritoneal reflection we feel that anterior resection is justified. In the group of patients previously mentioned, anterior resection might be extended to lesions located a few inches below the peritoneal reflection if complemental proximal colostomy is done. According to Gray,[64] a patient's chances for cure, with a lesion of the rectosigmoid, is diminished by no more than 3 per cent if the abdominal approach alone is used, perhaps not at all (Kirklin[65]).

For all other lesions of the rectum, it seems to us, the glands heading toward the aortic chain and along the levators should be the principal ones for attack. With these in mind it seems logical to conclude that the Miles operation or its modifications offer a better chance of cure than will less extensive excision with restoration of continuity.

The decision as to open or closed anastomosis is not too difficult to make. Whichever is easier for the operator to perform well should be selected, so long as his mortality rate remains in the neighborhood of 5 per cent. This relatively low rate is being achieved by more and more surgeons using either method. As emphasized by Rives,[66] it is more the manner of execution that counts rather than the method. If the morbidity and mortality can be further reduced appreciably by staged operations, then this plan, of course, should be

adopted. Otherwise, it seems that the advantages of primary resection and anastomosis far outweigh those of multiple procedures, except in the complicated case.

The use of complemental decompression can also be gauged by comparative morbidity and mortality studies. There is no question that long tube decompression, as well as increased knowledge of the physiology of peristalsis, have lessened the advantages of operative decompression. However, unless its disadvantages become more obvious we shall continue to use this measure.

The results obtained in carcinoma of the colon and rectum have kept general pace with the advances in surgical technic and knowledge. Nevertheless, we must not allow ourselves to become self-satisfied or complacent. The last word in treatment of patients with intestinal cancer is far from written, as witness the fact that many abandoned or maligned procedures find new applications with increased knowledge. It is doubtful whether any really new procedure can be devised. We should study diligently the lessons of the past and correlate them with present advances in the all-out effort to achieve further improvements for the unfortunate cancer victim.

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THE USES OF PLASTIC TUBES IN THE REPARATIVE SURGERY OF BATTLE INJURIES TO ARTERIES WITH AND WITHOUT INTRA-ARTERIAL HEPARIN ADMINISTRATION*

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BACKGROUND

DEBAKEY AND SIMEONE in an excellent review article[1] point out that 68.6 per cent of over 3000 amputations performed in two theaters of operation in World War II were necessitated by tissue loss alone, 19.5 per cent were due to arterial injuries *per se*, and 11.9 per cent were caused by gas gangrene and other infections. They indicate that the tremendous amount of tissue destruction caused by the speed and multiplicity of modern war missiles and the time lag between injury and treatment decide the fate of the majority of limbs before reparative surgery can be undertaken. It is possible, however, that in the event of another war the increasing number of civilian casualties from air raids may reduce this interval between injury and treatment. Furthermore, the enormous tissue destruction and loss of collateral circulation show clearly that the only hope for avoiding gangrene with these injuries lies in maintaining patency of the main artery to the limb—at least until post-traumatic edema subsides and collateral circulation becomes re-established.

The best methods for repairing these arteries are unfortunately impractical under battle conditions. The suture technics of Carrel and Guthrie will not bridge the gaps left by the loss of arterial substance. The technic of Blakemore[2] using venous-lined vitallium tubes preserves the principle of intima-to-intima coaptation, but is usually too time-consuming and complex for use under battle conditions by the average military surgeon. A simple reparative technic using lucite tubes was introduced toward the end of the last war. The method was not properly evaluated because of the unfavorable conditions during battle for making follow up observations and controlling the important variables. This investigation was undertaken to determine how well plastic tubes bridge gaps in arteries and the reasons for their relative success or failure. The ideal reparative technic for arteries ablated in battle should be simple, avoid thrombosis effectively, and use materials well tolerated in tissues.

Lucite, a methyl methacrylate polymer, has been shown to be relatively well tolerated in animal and human tissues. Polyethylene,† another synthetic plastic, is made by polymerizing ethylene under heat and pressure to hydro-

* The opinions or assertions contained herein are the private ones of the writer and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large. Submitted for publication January, 1949.

† The polyethylene tubing used in these studies was of formulation PHF, purchased from Surprenant Mfg. Co., 199 Washington Street, Boston, Mass.

carbon chains somewhat longer than those of paraffin. In addition to its chemical similarity to paraffin, polyethylene has the advantage of being flexible without plasticizers and in this respect is more suitable for replacing segments of arteries near joints.

TABLE I.—*The Coagulation Time (Minutes) of Blood in Contact with Various Surfaces*

Series	Polyethylene	Lucite	Glass	Paraffin	Collodion	No. of Comparisons	End Point	Diam. of Tubes (mm.)	Blood Used
Authors	11.5	—	5.3	12.4	12.5	30	Earliest sign of clotting	5	Canine
Hirschboeck	—	13.9	6.2	18.3	—	10	Complete clotting	10	Human

Ingraham, *et al.*[3] have reported that pure polyethylene caused minimal foreign body reaction and gliosis when implanted in the cerebral cortex of animals. They stressed the importance of using pure polyethylene, however, because any traces of the antioxidants or plasticizers used commercially to enhance its insulating or flexible properties have incited marked fibrosis and foreign body reaction. To establish the purity of the polyethylene used and to study its reaction in tissues, small pieces of polyethylene and lucite were inserted subcutaneously in the backs of 30 rats at the outset of this study. The animals were sacrificed at intervals postoperatively and the tissues surrounding the plastic studied histologically. Figure 1 shows that the tissue reaction at three months to pure polyethylene resembles that caused by the relatively well-tolerated lucite.

Clotting times were then performed under controlled conditions in glass and polyethylene tubes and in glass tubes lined with paraffin and collodion. The *in vitro* capacity of polyethylene for delaying coagulation is similar to that of lucite (Table I), being about twice that of glass and nearly as great as paraffin and collodion.[4] Surface tension studies (Table II) indicate that

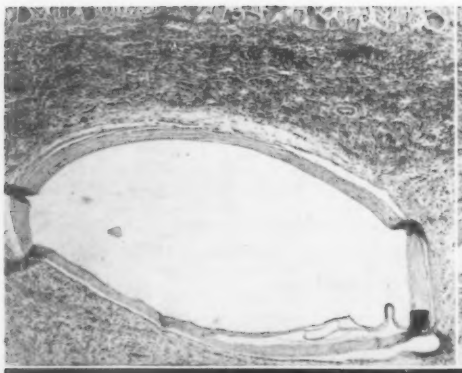
TABLE II.—*The Values (Gm/cm.) for the Adhesive Force Between Water and the Surfaces of Polyethylene and Glass. These Figures Are Compared with Hirschboeck's Values for Glass, Lucite, Paraffin and Collodion*[5] *and the Established Value for Glass.*[6]

Series	Polyethylene	Lucite	Glass	Paraffin	Collodion
Authors	+0.034	—	+0.073	—	—
Hirschboeck	—	+0.038	+0.053	−0.037	+0.034
Harkins and Brown	—	—	+0.0736	—	—

polyethylene, like lucite, follows Lampert's rule that the capacity of a surface for delaying coagulation is inversely proportional to its "wettability."[4-7]

With this background polyethylene tubes were first tested by bridging gaps in the aorta of dogs with a technic similar to that of Hufnagel, who reported permanent anastomosis of the thoracic aorta of dogs using lucite tubes.[8]

FIG. 1A



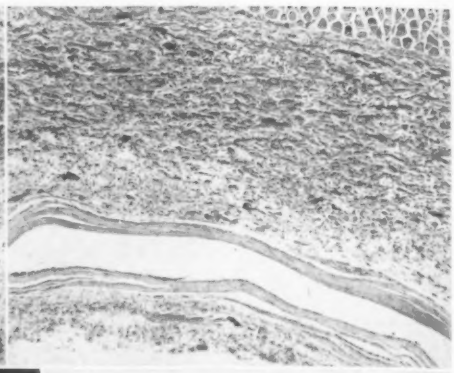


FIG. 1B

FIG. 2

FIG. 3

FIG. 4

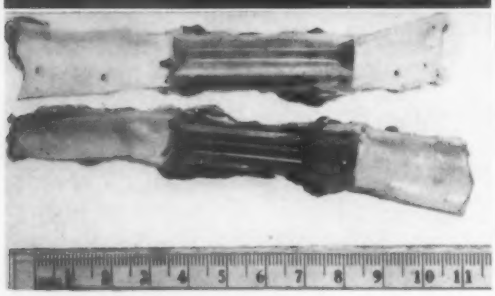


FIG. 5

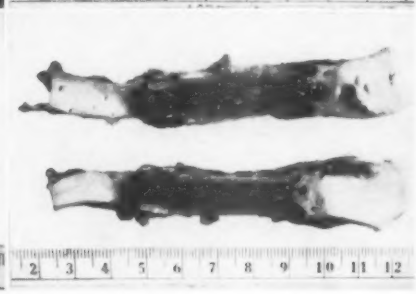


FIG. 1.—The tissue reaction to polyethlene (A) and lucite (B) three months after subcutaneous insertion into rats. The fibrous capsule surrounds the space from which the plastics were removed during fixation. The width of each piece of plastic represented by the diameter of the capsule was about 2 mm. while the length approximated 1 cm.

FIG. 2.—Roentgen ray of the thoracic aorta 12 months after anastomosis with a polyethylene tube of 5 mm i.d. Arrows indicate the ends of the tube.

FIG. 3.—The aorta and tube of the animal in Figure 2, showing the tissue proliferation bridging over the vulnerable tube-vessel junction, thus inhibiting thrombosis.

FIG. 4.—An aorta and tube partially thrombosed nine months postoperatively.

FIG. 5.—A completely thrombosed aortic intubation in a dog sacrificed six months postoperatively. Both ends of the clot are almost completely covered with endothelium.

I. Aortic Intubations

MATERIALS AND METHODS

Description of the polyethylene tubes. Stock polyethylene tubing of 5.5 and 7.5 mm. i.d. was divided into lengths of 4 to 4.5 cm. and turned to a wall thickness of about 1 mm. The internal diameters were chosen to stimulate the size of the human femoral artery. Holding ridges of 1 mm. width and height were left about 5 mm. from each end of the tube. The ends of the tube were turned almost to knife-edge thinness and then flared by slowly inserting a smooth metal die heated to the softening temperature of the polyethylene. If any flaw was found on any part of the tube, it was discarded. The tubes were sterilized in 70 per cent alcohol or 1 to 1000 zephiran for 18 hours prior to operation.

Operative technic. The animals were premedicated with 0.25 grain of morphine, 0.01 grain of atropine and anesthetized with 6 per cent nembutal (1 cc. per 5 pounds body weight). Supplementary doses of nembutal were given later as needed through a plastic tube introduced into the vein of the front leg after the method of Zimmermann.[9] Positive pressure oxygen was given during the operation through an intratracheal tube of Koroseal by a mechanical respirator.

The seventh rib was resected and the pleural cavity entered through its bed. Five pairs of intercostal arteries were ligated and divided to make patency of the anastomosis more critical to the animal's survival. Division of these intercostal arteries probably eliminated the intercostal-to-intercostal collateral routes and impeded the subscapular-intercostal and internal mammary-intercostal anastomoses. It did not, however, interfere with the internal mammary-inferior epigastric pathways of collaterial circulation. The aorta was then freed from the thoracic duct and vagus nerve and the Gross aortic clamps applied for hemostasis.[10] The aorta was then divided or a short segment excised and the Hufnagel aorta spreader introduced distally to facilitate the atraumatic insertion of the polyethylene tube.[11] The limited excision was done in this study in an effort to reduce the strain on the ligatures and avoid subsequent aortic rupture from this cause. The tube was ligated in place with large braids of No. 2 silk strands, as suggested by Hufnagel,[8] to give multiple point fixation of the aortic wall and prevent its necrosis and rupture. The ligature behind the holding ridge was applied tightly while the one nearest the flare was tied more lightly. The tube and vessel were irrigated with saline and the proximal end inserted and ligated in a similar manner. The distal clamp was then removed and the proximal clamp released gradually while the animal was placed in a moderate Trendelenburg position. This obviated the hypotensive effect of splanchnic pooling so that usually only slight tachycardia was noted on release of the clamps.[12] The period of aortic occlusion rarely exceeded ten minutes and no paraplegia from this cause occurred. The aorta was repleuralized and the chest closed with chromic pericostal and interrupted cotton sutures.

Penicillin in saline solution (500 units/cc.) was used to irrigate the pleura periodically during the operation and penicillin in oil was given intramuscularly for several days postoperatively. No heparin or other anticoagulants were given at any time to these animals.

Postoperative observations. The anastomoses were studied postoperatively by observations on the oscillations,* strength, and warmth of the hind quarters. Absence of paraplegia is good evidence of patency during the immediate postoperative period. Later in the postoperative course the development of collateral circulation makes this a less reliable sign. At about three months postoperatively, roentgenograms of the aorta were taken using thorotrast or 70 per cent diodrast intravenously and repeated just prior to sacrifice from 6 to 12 months postoperatively, when pathologic studies were made.

RESULTS

A. *Initial group.* In the initial group of 14 aortic anastomoses, six dogs died on an average of ten days postoperatively from aortic rupture associated with clotting in the polyethylene tube. In four of the six aortic ruptures the tubes were too large, causing intimal trauma at the time of insertion and subsequent pressure necrosis of the aortic wall. Three animals developed thrombosis and paraplegia and were sacrificed. Some of the thromboses in this initial group were due to intimal damage during insertion and/or roughness and asymmetry of the tube. The anastomoses in two animals, one weighing 9 Kg. with a tube of 5.5 mm. i.d. and a 21 Kg. dog with a tube of 7.5 mm. i.d., remained open permanently. These animals were sacrificed 12 and nine months postoperatively.

B. *Second series.* Table III shows the results of a series of anastomoses with tubes of 7.5 mm. i.d. without the above-mentioned technical flaws. Two of the nine anastomoses remained permanently functional. Three of the fatalities were from hemorrhage and three from mesenteric embolism, two of the latter following large doses of intravenous thorotrast. The average length of survival in the fatal anastomoses was 51 days.

Pleural adhesions of varying density were found in all the animals autopsied more than three months postoperatively. Repleuralization of the tube and aorta did not completely prevent the adherence of pleura to the tube and adjacent tissues. The ends of the aorta, separated by the tube, were united in a few weeks by a neomembrane composed largely of fibrous tissue completely enveloping the tube. The chromic pericostal sutures and the intrapleural penicillin could not be incriminated in the fibrotic reaction, since the

* Oscillometry was recorded as 4 plus, maximal; 3 plus, moderate; 2 plus, decreased; 1 plus, minimal; and 0, absent. From 2 to 4 plus is considered normal range while 1 plus or 0 usually means decreased blood flow to the limb from thrombosis, embolism, or other causes. Oscillometric studies are valuable as corroborative data when trends and not individual observations are considered, but they do not compare with angiography for accuracy and amount of information given.

animals autopsied up to three weeks postoperatively were free of adhesions and widespread inflammatory reactions. In none of these animals was there any evidence of pleural sepsis.

C. *Permanent intubations.* Of the four permanent intubations, one was completely free of clots, two were partially thrombosed and one was completely thrombosed. Figure 2 shows a roentgenogram of the completely patent anastomosis 12 months postoperatively. Oscillations remained normal throughout the postoperative course. Figure 3 shows the appearance of the tube and aorta at the time of sacrifice. The tissue proliferation (connective tissue lined with endothelium) characteristic of the permanent intubations can be seen at both ends of the tube bridging over the vulnerable tube-vessel junctions, thus inhibiting thrombosis.

TABLE III.—*Results of Anastomoses of the Thoracic Aorta in Dogs with Polyethylene Tubes*

No.	Weight in Kg.	Time of Survival	Cause of Death	Condition of Tube	Comment
1	18	8 months	Sacrificed	Small clot in tube	Roentgen ray showed patency
2	18	18 days	Mesenteric embolism	Partial thrombosis at distal tube-vessel junction	
3	18	3 months	Mesenteric embolism	Small clots at tube-vessel junctions	Oscillations disappeared after 40 cc. thorotrast and returned after embolus
4	16	4 hours	Massive hemothorax	Fibrin deposition in tube and at proximal tube vessel junction	
5	21	4 months	Mesenteric embolism	Partial thrombosis at proximal tube-vessel junction	Embolism followed 40 cc thorotrast and recurred
6	21	11 days	Aortic aneurysm with leakage	Small clots at tube-vessel junctions	
7	21	4 days	Thrombosis of tube	Complete thrombosis of proximal end of tube	
8	19	6 months	Sacrificed	Complete thrombosis of long duration	Marked collateral circulation by roentgen ray
9	21	4 months	Massive hemothorax	Complete thrombosis of recent origin	Aortic rupture high above tube; marked cardiac hypertrophy

The two permanent intubations with small intraluminal clots had one to two plus oscillations during most of their postoperative course. The tubes in the aortograms were less clearly defined, also indicating partial thrombosis. Figure 4 shows one of these partially thrombosed tubes at autopsy.

Roentgen ray studies of the animal with complete thrombosis of the tube showed the complete blockage and marked dilatation of the collateral channels. The internal mammary arteries, greatly enlarged and tortuous, anastomosed with equally large inferior epigastric arteries, but no notching of the ribs was apparent. The subscapular arteries were also moderately expanded, but the lowermost intercostals were not visible. Oscillations were moderate the first month in this animal, slight during the second month and absent there-

after despite normal function of the hind legs. Figure 5 shows this tube and aorta at the time of sacrifice.

COMMENT

Hufnagel's five permanent anastomoses of the aorta with lucite tubes in a series of 15 intubations were notable for the complete absence of clot formation. Nine of the ten fatal intubations were also free of clots.[8] These results contrast sharply with the prevalence of clotting in this study of polyethylene and suggest that lucite tubes are superior to those of polyethylene in respect to the avoidance of thrombosis. The larger sizes of the lucite tubes and aortas, however, must be considered as contributing to the superior results. The significance of this size factor will be discussed in the next section dealing with intubations of the femoral artery.

II. Intubations of the Femoral Artery

MATERIALS AND METHODS

Description of the polyethylene tubes. Polyethylene tubing of 2.7 mm. i.d. and 3.5 mm. o.d. was cut into lengths of 2 to 2.3 cm. The ends were flared with a hot die. Holding ridges were placed around the tubes by applying melted polyethylene about 3 mm. from each end of the tube. Some of these tubes were soaked in heparin (sodium heparin, Lederle, 10 mg. per cc.) for one month before operation. This was done because surface tension studies with polyethylene tubing indicated that the polyethylene absorbed water over a period of days and therefore might absorb aqueous heparin.[4] Other tubes were lined with silicone film,* which inhibits blood coagulation, by filling their lumina with silicone and silicone diluted with toluene to concentrations of 1/100 and 1/200. The toluene was baked off and the tubes rinsed for several hours in distilled water.

Description of the lucite tubes. Lucite tubes, 2 to 2.3 cm. long, were turned from stock tubing of 3 mm. i.d. with ridges about 3 mm. from each end. The ends were flared with a warm die, making them similar in shape to the polyethylene tubes but slightly larger in internal diameter. At no time was the inner surface of the tubes scratched or handled roughly. All tubes were carefully inspected for flaws and discarded if any irregularity or asymmetry was found.

Operative technic. The femoral artery was exposed from just below the groin to just above the knee. The long saphenous artery, which arises medially from the femoral artery about 5 cm. below the inguinal ligament, was freed and its branches divided. A polyethylene side tube about 60 cm. long, 1 mm. o.d. and 0.4 mm. i.d., was threaded into the long saphenous artery for about 1 cm. and held in place with four cotton ligatures. The other end of this tube

* The silicone was General Electric's Dri Film 9987 usually used on glass surfaces. The silicone for plastic surfaces was not available.

was led with a long flexible needle subcutaneously and dorsally through the skin of the costovertebral area, a location inaccessible to the animal's teeth. Through this tube 35 per cent diodrast was injected at 24-hour intervals postoperatively and the distal femoral artery visualized by arteriography (Fig. 6). A stylet was placed in the end of the tube between injections to prevent retrograde bleeding and clotting in this side tube.

The branches of the femoral artery were ligated and divided from above this long saphenous artery to the bifurcation of the femoral into anterior tibial and popliteal arteries. Bull dog clamps were applied, the femoral artery divided, and the adventitia retracted from the cut ends of the vessel. After the ends of the artery were irrigated with saline the plastic tube was inserted, using a new instrument designed to retract the arterial walls. The tube was

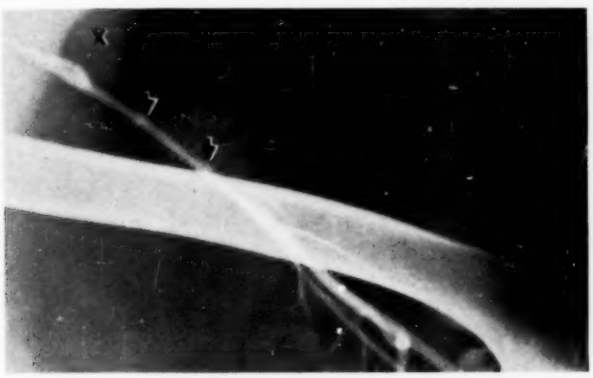


FIG. 6.—A polyethylene tube bridging a gap in the femoral artery of a dog two days postoperatively. Arrows mark the ends of the tube (note increased capacity) and X, indicates the small polyethylene side tube in a branch of the femoral artery proximal to the anastomosis.

ligated in place with No. 20 cotton ligatures on each side of the holding ridges and the adventitia replaced over the ends of the tube.

The instrument used to retract the vessel walls was constructed by attaching semicircular steel rockers to the tips of an outside caliper by means of a steel pivot (Fig. 7). Four barbless hooks were connected by silk suture material to the ends of the rockers. By adjusting the screwlock on the caliper, vessels of various sizes could be spread in the form of a square larger than their internal diameter (Fig. 7). This instrument has facilitated the insertion of these artificial tubes and minimized intimal damage during insertion, thus obviating subsequent thrombosis from this cause.[13]

In two animals with otherwise identical technic the ends of the divided artery were ligated. In one animal circular ligatures were used and in the other the Poppen type of suture ligature was employed, which invaginates the arterial wall and apposes the intima.[14]

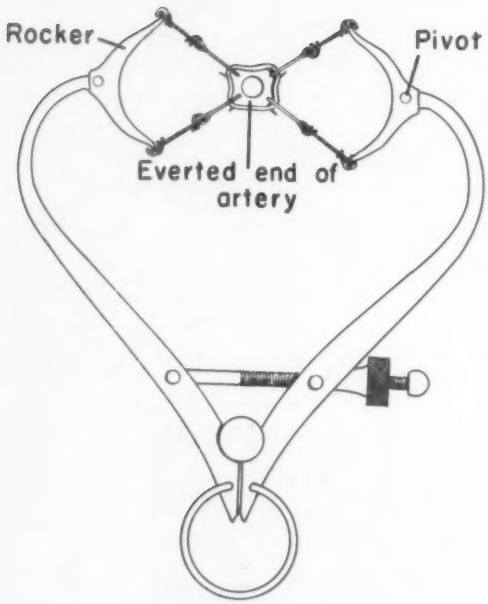


FIG. 7.—Diagram showing vessel spreader. Lower portion represents a four-inch caliper with screw-lock and spring. At the upper ends are the rockers attached with steel pivots. Four silk threads are shown leading to the hooks which retract the vessel walls.

Intima coaptation technics were also studied, *e.g.*, suture anastomosis and polyethylene tubes lined with veins after the method of Blakemore, *et al.*[2] (Fig. 8).

Postoperative observations. These anastomoses were studied postoperatively by daily arteriograms as described previously. In addition, observations on the oscillations, strength, and warmth of the extremities were made three times daily and the artery examined under anesthesia just prior to sacrifice.

RESULTS

A. Anastomoses with plastic tubes.

Duration of patency. Table IV shows a summary of the results in typical series of polyethylene and lucite intubations of the femoral

TABLE IV.—*Results of Anastomoses of Femoral Arteries of Dogs with Polyethylene and Lucite Tubes*

Dog No.	Weight in Kg.	Artery	Tube	Roentgen Ray Study of Course in Hours		Duration of Patency in Days
				Patent	Thrombosed	
1	28	Right	Polyethylene	48	72	2
		Left	Polyethylene	48	60	2
2	29	Right	Polyethylene	48	72	2
		Left	Polyethylene	72	80	3
3	23	Right	Polyethylene	10	24	½
		Left	Polyethylene	10	24	½
4	33	Right	Polyethylene	48	72	2
		Left	Polyethylene	48	72	2
	Average 28					Average 1.8
1	42	Right	Lucite	96	Dog sacrificed*	4
		Left	Lucite	24	48	1
2	35	Right	Lucite	72	96	3
		Left	Lucite	120	Dog sacrificed*	5
3	28	Right	Lucite	96	120	4
		Left	Lucite	48	72	2
4	35	Right	Lucite	72	96	3
		Left	Lucite	72	96	3
	Average 35					Average .13

* Dogs sacrificed to establish patency, as leakage from side tube prevented roentgen ray visualization.

artery. Six out of eight anastomoses with polyethylene tubes were open on the second day on roentgen ray study with an average duration of patency of slightly less than two days. The lucite tubes showed an average duration of patency of slightly over three days with six out of eight intubations open on the third day. The average period of patency of the six anastomoses using silicone-lined tubes or the four heparin-soaked tubes was not longer than with the untreated polyethylene tubes. Figure 6 shows a polyethylene tube in dog No. 4 on the second postoperative day.

Clot formation. Figures 9, 10 and 11 show the development of collateral circulation following thrombosis of the lucite tubes in dog No. 7. These

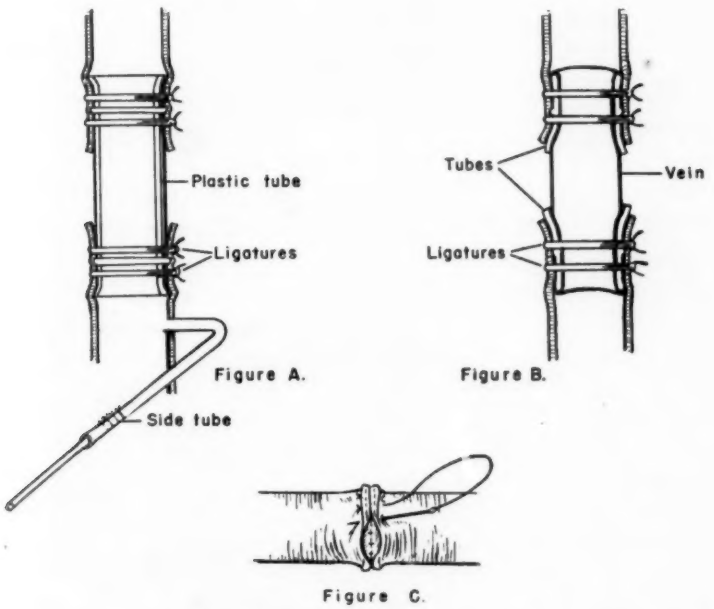


FIG. 8.—Three technics for reconstructing vessels. A. Plastic tube anastomosis. Note polyethylene side tube in a branch of the femoral artery. B. Venous-lined tubes, reproduced from Blakemore.[2] C. Suture anastomosis redrawn from Gross and Hufnagel.[10]

roentgen ray films are typical of others showing the same process occurring with polyethylene intubations. Following thrombosis the oscillations dropped to 1 plus or zero, but the hind legs never felt significantly cooler than the front legs. Emboli were seen in several roentgenograms, partially or wholly blocking the flow in the femoral, anterior tibial, or popliteal arteries (Fig. 9). In some instances their origin could be traced to the tube anastomosis by serial films. No appreciable difference was noted in the process of clot formation and extension or the development of collateral circulation in these siliconed, heparin-soaked and untreated polyethylene tubes.

Reaction to the lucite and polyethylene tubes. The adjacent tissues adhered

FIG. 9

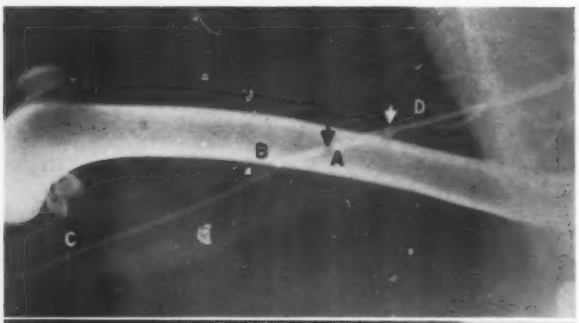


FIG. 10

FIG. 11

FIG. 9.—A lucite tube in the femoral artery on the fourth postoperative day. The arrows indicate the extent of the tube. (A) Demonstrates the clot almost completely occluding the distal end of the tube. (B) Shows an embolus at the bifurcation of the femoral artery completely blocking the anterior tibial artery and protruding into the popliteal artery. (C) Another small embolus in the popliteal artery. (D) Shows the narrowing of the femoral artery proximal to the tube and the development of collateral circulation which follows thrombosis of these tubes.

FIG. 10.—The lucite tube in Figure 9, 24 hours later showing complete thrombosis and further development of collateral circulation.

FIG. 11.—The other leg of the animal in Figures 9 and 10 showing the collateral circulation 48 hours after complete thrombosis of the tube.

to and enveloped the plastic tubes in a fibrous sheath of slight to moderate thickness with no discernible difference between the two plastics used.

B. Arterial ligations.

With the same operative destruction of collateral circulation as in the intubation technics, the two animals with femoral artery ligation had cold legs for about 24 hours and negative oscillations for about two weeks. After the 24-hour period following operation the collateral circulation developed as with the arterial intubations. Propagation of clots in the first few postoperative days was negligible with both ligation and intubation technics, but with the passage of weeks propagation from the tube thrombi seemed to be somewhat greater than following either type of arterial ligation.

C. Intima coaptation technics.

Examination of a suture anastomosis of the femoral artery at the end of a week showed complete patency with no fibrin deposition or clotting and the beginning of intima-to-intima union. In an anastomosis using venous-lined polyethylene tubes, roentgenograms showed patency at the end of a week. At the end of three weeks the tube was free of clots and the union between venous and arterial intima was complete. Reaction to the polyethylene tube, however, had thickened the venous wall and nearly occluded the lumen at the proximal tube-vessel junction.

DISCUSSION

The fact that some aortic intubations remain patent permanently whereas all femoral intubations clot about the third day may be explained in several ways. The pattern of blood flow in the aorta depends among other things upon the diameter of the vessel and the velocity of flow. Both of these factors vary in systole and diastole. The density and absolute viscosity of the blood, which also influence flow patterns, may or may not be constant. In spite of these variables, numerical values have been substituted in the formula for the Reynold's number.* The figure obtained for the Reynold's number during systole in the thoracic aorta of dogs is well above 2000, the critical level where laminar or viscous flow becomes turbulent in smooth pipes. The irregularity at the tube-vessel junctions further predisposes to turbulence.[15-17] Assuming that the values are correct, the significance of this higher velocity and possible turbulence in the aorta, as opposed to the femoral artery and smaller vessels, lies in the concomitant increase in the erosive power of the blood stream on freshly formed clots, since the shearing stress between circulating blood and vessel wall varies with the velocity and is much greater for turbulent than for laminar flow.†[16] Another of the possible explanations is that the large volume flow in

* The Reynold's number equals the velocity of flow multiplied by the diameter of the vessel and divided by the kinematic viscosity of the circulating fluid. Kinematic viscosity equals the absolute viscosity divided by the density of the fluid.[15]

† The fact that the shearing stress also varies inversely with the diameter of the vessel is of less importance in this range of velocities and Reynold's numbers.

the aorta may dilute or remove more effectively the locally liberated substances which promote clotting.

These considerations may explain the embolic phenomena observed frequently following the aortic anastomoses with polyethylene tubes as well as the capacity of these anastomoses for remaining open permanently. They also emphasize the important influence of the vessel size on the duration of patency of an anastomosis and qualify the apparent superiority of the larger lucite tubes over the smaller polyethylene tubes in the aortic and arterial anastomoses. In addition, these concepts modify the predictions of efficacy of these femoral intubations in the larger arteries of humans. This does not mean, however, that the results in the aortas of dogs can be extrapolated to the similar sized femoral arteries of man, since the pressure gradients (and hence velocities) are different in central and peripheral vessels.

Besides the arterial size, other technical factors which influence the duration of patency are: (1) The inner smoothness, over-all symmetry, and suitable size of the tube, (2) the intrinsic capacity of the tube for repelling water and delaying coagulation and (3) the amount of trauma to the arterial intima during insertion.

Although fatal hemothorax was a common complication in the aortic intubations, secondary hemorrhage following intubations of the femoral artery was a rare complication and usually due to tubes excessively large for the artery under repair. The greater retraction of the elastic tissue in the wall of the aorta and the higher pressures in the upper aorta (especially with a thrombus occluding the tube) probably increased the strain on the ligatures and contributed to the aortic ruptures.

Although the plastic tubes in the femoral arteries were thrombosed after two days, their gradual occlusion stimulated collateral circulation and avoided the temporary period of acute ischemia which followed arterial ligation. The marked stimulus to collateral circulation of the tube anastomoses was also demonstrated by the animal with an aortic anastomosis which maintained blood supply to the abdominal aorta sufficient to sustain normal function despite complete thrombosis of the tube and extensive operative destruction of collateral circulation.

The greatly prolonged durations of patency of the suture anastomosis and venous-lined polyethylene tubes show the superiority of these methods over the plastic tube anastomoses with respect to avoidance of thrombosis. Experienced vascular surgeons can obtain about 50 per cent permanent patencies with suture anastomoses of the dog's femoral artery. Blakemore has reported that his nonsuture method using venous-lined vitallium tubes is 85 per cent successful in day-old contaminated wounds in dogs, as compared with 40 per cent patency following suture anastomosis under these conditions.[2]

These facts plus the high percentage of thromboses which followed the Blakemore reparative technic in arterial injuries of the last war point up the difference between the results of intubations done under the ideal circumstances

of the experimental laboratory and those done under battle conditions. In battle injuries to arteries repaired with plastic tubes, assurance of patency of the anastomoses beyond the period of post-traumatic edema would seem, from these considerations, to require supplementary anticoagulant therapy.

III. Intra-Arterial Heparin Administration

Materials and Methods

Description of the tubes. The polyethylene tubes and the intubations of the femoral arteries were the same as described in the preceding section.

Heparinization. Intra-arterial heparin was infused proximal to the anastomosis by the same route that 35 per cent diodrast was injected for the arteriograms described previously, *i.e.*, through a subcutaneous polyethylene side tube from the skin of the costovertebral area to the lumen of the long saphenous artery (Fig. 6). Sodium heparin, Lederle, (0.25 mg. per Kg. of body weight in 10 cc. of saline) was given shortly after operation into the left femoral artery and repeated every two hours, in some animals every three hours, day and night. The right side tube was used only for postoperative arteriograms. Unlike human beings with arterial injuries, dogs continually move about following operation, and unless the side tube has a relatively thick wall, it will kink and leak after a few days of heparin administration. The side tubes in this preliminary study of intra-arterial heparinization were too thin, and in most instances subcutaneous leakage of heparin necessitated cessation of therapy about the fifth day. A thicker side tube is now being used (0.4 mm. i.d. and 1.0 mm. o.d.) which is attached to the main tube in a manner that eliminates the necessity of intubating a branch of the femoral artery, thereby simplifying the operative technic and sparing another artery for collateral circulation.

Postoperative observations. The follow-up observations were made with oscillometry and periodic arteriograms in the manner described previously. The anastomosis of the uninjected artery reflected the systemic effect of the intra-arterial heparin administration and the irrigated intubation showed the combined local and systemic effect of the heparin. By contrasting the results in the two femoral intubations, the local effect of heparin could be evaluated in a series of animals.

Since dogs as well as human beings vary in their responses to a given dose of heparin, coagulation times were done preoperatively and at intervals postoperatively to evaluate the daily heparin effects in these animals. Investigators in this field have been impressed with the inadequacies of coagulation times in evaluating the effect of heparin. Control clotting times vary widely even in the same animal from time to time. One of the factors responsible is the varying amount of trauma incident on transferring blood from the animal's vein to the tube. Another factor is the ambiguous nature of most endpoints. In addition, the actual fluidity and coagulability of the blood probably varies normally from time to time according to the relative concentrations of heparin and

thromboplastin (and other clotting substances) in the circulating blood.[18-20] The concentration of heparin cofactor in the plasma may also vary and thus alter the response to a given dosage of heparin.[21, 22]

An attempt was made to control the first factor by letting the blood flow freely through a No. 20 B-D needle with exclusion of air into the clean syringe lined with liquid petrolatum after uniformly direct venepunctures. The sample was then transferred carefully to a glass tube of 5 mm. i.d., bent in the form of a semicircle of 6 cm. radius.[23] This tube was moved uniformly at definite intervals until complete clotting occurred. In an attempt to make the end-points more precise the times of the earliest definite fibrin precipitation and the complete immobility of the blood in the tube were measured by stop watch

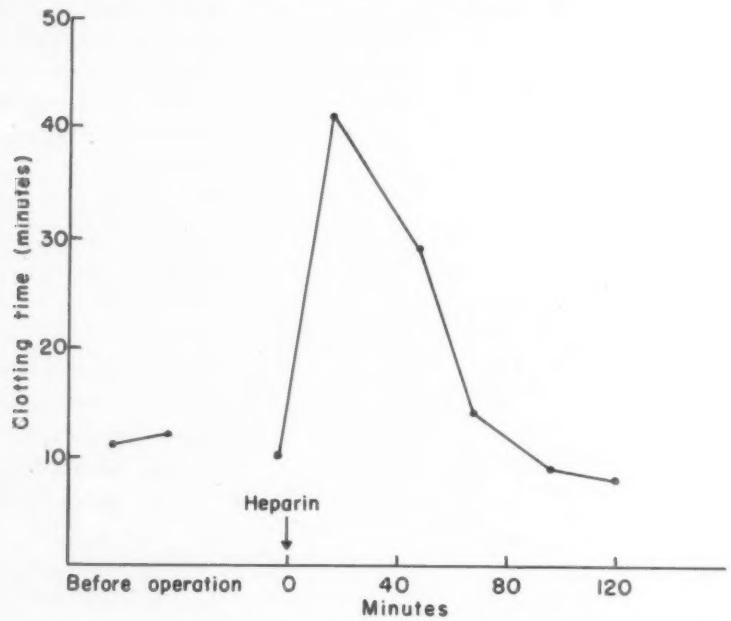


FIG. 12.—The response of the venous clotting time to the intra-arterial injection of 4 mg. of sodium heparin in 10 cc. of saline in a 16 Kg. dog.

and these two durations averaged to determine the clotting time for each sample. Since it has been repeatedly emphasized that both phases of coagulation are proportional in length, the average of the duration of the first phase (prothrombin conversion to thrombin) and the duration of the first plus the second phase (fibrinogen conversion to fibrin) should give a more reproducible value for the coagulability of each sample.[23]

RESULTS

The above procedures have been done on eight dogs. Only two will be reported here because technical difficulties made the results in the other animals hard to interpret, although the general pattern of reactions was similar.

Dog 1 (16 Kg.). Four mg. of sodium heparin was given in 10 cc. of saline into the left artery every two hours for 120 hours, until subcutaneous leakage necessitated cessation of therapy. Four of the 60 doses scheduled were omitted, leaving a total of 216 mg. of sodium heparin in 540 cc. of saline given during this period. Figure 12 shows the marked prolongation of coagulation time caused by 0.25 mg. heparin/Kg. of body weight on the first day. This response became less marked during the next four days.

The left or heparinized artery was patent on the fourth postoperative day (Fig. 13). The right or control artery was open by arteriography on the third day but thrombosed on the fourth postoperative day. The right or control artery exceeded the average duration of patency in polyethylene intubations of the femoral artery by about 24 hours. The left or heparinized artery exceeded the average duration of patency by at least 48 hours.

Dog 2 (24 Kg.). Six mg. of sodium heparin was given in 10 cc. of saline into the left artery every three hours for 114 hours until leakage from the side tube prevented further therapy. These 38 injections totaled 228 mg. of heparin in 380 cc. of saline. The clotting time response to this 0.25 mg. of heparin per Kg. of body weight was slight (not more than double the control level) throughout the period of heparinization.

The left or heparinized artery was patent on the fourth postoperative day (Fig. 14). Oscillations remained about 2 plus until the seventh postoperative day. The right or control anastomosis was patent by roentgen ray on the second day and thrombosed on the third postoperative day. The right or control artery had the same duration of patency as the average of polyethylene intubations in unheparinized animals. The left or heparinized anastomosis exceeded this average duration of patency by at least 48 hours and possibly by 96 hours.

FIG. 13

FIG. 14

FIG. 13.—The roentgen-ray of the heparinized artery of the animal in Figure 12 on the fourth postoperative day. Arrows indicate the ends of the polyethylene tube and X, a leak in the side tube which prevented further intra-arterial heparin administration on the fifth postoperative day.

FIG. 14.—An arteriogram of the heparinized femoral artery on the fourth postoperative day. Arrows indicate the ends of the polyethylene tube and X, a leak in the side tube which prevented further intra-arterial heparinization on the fifth postoperative day.

DISCUSSION

Intravenous anticoagulants are often contraindicated in war wounds, since the latter are frequently multiple and complicated by latent visceral bleeding. Furthermore, the administration and control of anticoagulants are often imprac-

tical under battle conditions. It occurred to the author that heparin might be given intra-arterially proximal to the anastomosis with constant or intermittent infusions in concentrations which would prove effective locally and yet not raise the general clotting time to a dangerous level. Heparin was chosen for intra-arterial use, because it is a potent, physiologic anticoagulant which acts instantly in a physicochemical manner.[20] It is also rapidly inactivated by nontoxic protamine sulfate given intravenously.

Although these investigations are still in progress, using a different method of intra-arterial heparin administration, two cases have been presented since they represent the general pattern of the results to date.

Although the clotting time responses to intra-arterial heparin injections in dog No. 1 became less marked with each succeeding postoperative day, the control artery seems to have obtained some systemic heparin effect, since it exceeded the average duration of patency by about 24 hours. The left or heparinized side remained patent even longer and appears to have had an added local effect.

A lack of systemic heparin effect is indicated by the clotting time studies in dog No. 2, which received the same 0.25 mg. of heparin per Kg. of body weight every three hours instead of every two hours as in dog No. 1. This lack of general effect is further evinced by the thrombosis of the uninjected artery in the usual length of time. A significant local effect is suggested by the greatly prolonged patency of the left or heparinized anastomosis.

These two examples suggest a definite local action of the intra-arterial heparin in doses not generally effective or dangerous. Although these are typical of other results, the statistical proof of this idea awaits further investigation. Furthermore, the mechanical effect of local irrigation must be ruled out by injecting similar amounts of saline without heparin in the control arteries.

Bleeding into the incision was the only complication of this technic, and its rare occurrence was due to copious leakage of heparin subcutaneously. If this route of heparin administration proves effective, it may be equally advantageous to give vasodilators in this manner, thereby delivering the various agents to the important arterioles of the muscles and deeper structures, and inducing a local hyperemia by dint of the borrowing-lending mechanism of blood distribution.[24-26] Antibiotics may likewise prove more effective by this route.

SUMMARY

1. In a preliminary study the reaction to pure polyethylene in the subcutaneous tissues of rats was similar to that caused by the relatively well tolerated lucite. The capacity of the polyethylene surface for delaying the *in vitro* coagulation of blood was also found to be similar to lucite, being about twice that of glass and nearly as great as paraffin and collodion. Surface tension studies in glass and polyethylene tubing showed that polyethylene, like lucite, follows Lampert's rule that the capacity of a surface for delaying coagulation is inversely proportional to its "wettability."

2. Polyethylene tubes were used to bridge gaps in the thoracic aorta of dogs after the method of Hufnagel.

In an initial group of 14 anastomoses, two polyethylene tubes remained patent for periods of 9 and 12 months when the dogs were killed. Half of the deaths in this group were due to aortic rupture with fatal hemothorax. In a second series of nine intubations, five animals were apparently healthy at the end of three months. Two of these five later developed fatal mesenteric embolism following aortograms with large doses of intravenous thorotrast. Two remained well for periods of six and eight months when they were killed.

Of the four permanent intubations one was completely patent 12 months postoperatively, two were partially thrombosed, and one was completely thrombosed. Marked enlargement of collateral pathways sustained normal function in the dog with complete thrombosis.

3. Anastomoses of the femoral artery with lucite and polyethylene tubes were performed with a new instrument for facilitating the insertion of artificial tubes. They were followed by frequent oscillometric examinations and daily arteriograms. The anastomoses with plastic tubes were compared with arterial ligations, suture anastomosis, and an anastomosis with venous-lined polyethylene tubes.

The average duration of patency of the polyethylene tubes was two days, while the slightly larger lucite tubes remained patent for three days. This average period of patency in polyethylene intubations was not prolonged by lining the tubes with silicone or soaking them in heparin preoperatively. During and after thrombosis of these tubes abundant collateral circulation developed and the limb was never acutely ischemic. Conversely, the animals with arterial ligations developed markedly ischemic limbs for the 24-hour period following ligation. The intima coaptation technics were much superior to the plastic tube anastomoses in respect to the avoidance of thrombosis. Since these more physiologic technics are usually impractical under battle conditions, further study of the simple anastomoses with plastic tubes was undertaken using supplementary anticoagulant therapy.

4. Because intravenous anticoagulants are contraindicated in most war wounds, study was initiated on a method for giving intra-arterial heparin proximal to the anastomoses of the femoral artery. The heparin was infused through the left side tube used for postoperative arteriograms and the right or uninjected artery acted as a control. Venous clotting times were also done to evaluate the systemic effect of the intra-arterial heparin. Typical cases were presented to indicate the kind of results which have occurred to date. They suggest that an adequate local effect may be achieved without prolonging the general clotting time significantly.

CONCLUSIONS

1. Pure polyethylene, like lucite, is relatively well tolerated in the tissues surrounding the femoral artery of dogs and in the subcutaneous tissues of

dogs and rats. The mediastinal tissues of dogs also showed slight to moderate reaction to pure polyethylene.

2. Polyethylene has a capacity for delaying the *in vitro* coagulation of blood which is similar to that of lucite, being about twice that of glass and nearly as great as paraffin and collodion.

3. Polyethylene repels water relatively well and, like lucite, follows Lampert's rule that the capacity of a surface for delaying coagulation is inversely proportional to its "wettability."

4. Polyethylene tubes will permanently bridge gaps in the thoracic aorta of dogs. Many of these anastomoses, however, are complicated by thrombosis, embolism, and aortic rupture.

5. Anastomoses of the femoral arteries of dogs with polyethylene and lucite tubes have average durations of patency of two and three days, respectively. Lining the polyethylene tubes with silicone or saturating them with heparin preoperatively did not increase the average duration of patency.

6. A new instrument for retracting the walls of arteries facilitates the insertion of these artificial tubes.

7. Although the plastic tube anastomoses are inferior to intima coaptation technics in respect to the avoidance of thrombosis, their gradual occlusion over a period of days stimulates collateral circulation and prevents the marked ischemia which follows arterial ligation.

8. In battle injuries to arteries repaired with plastic tubes, assurance of patency of the anastomoses beyond the period of post-traumatic edema would probably require supplementary anticoagulant therapy. Although intravenous anticoagulants are usually impractical in war wounds, a new method for the intra-arterial administration of heparin has shown promise and merits further study.

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ACUTE PANCREATITIS*

A CLINICAL EVALUATION AND REVIEW OF 154 CASES

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TWENTY YEARS AGO, one of us had the opportunity of reviewing 88 cases of acute pancreatitis with Dr. William Linder.[35] The present analysis includes an additional 66 cases, a total of 154 cases operated upon between 1913 and 1948. In our paper of 1929, we stressed the importance of diagnosis before abdominal section. The former concept, that acute pancreatitis can only be diagnosed at the operating table, is no longer true. Fitz indicated that this abdominal catastrophe should be suspected whenever violent epigastric pain is followed by vomiting and collapse. This occurs in fulminating cases. Little can be learned or done about this type, but acute pancreatitis, if borne in mind whenever an acute abdominal mishap presents itself, offers no greater difficulty in diagnosis than any other surgical condition.

The pathogenesis of acute pancreatitis, its differential diagnosis and treatment, will be discussed in some detail. The accompanying tables are meant to convey the pertinent statistical findings in the 154 cases analyzed.

ETIOLOGY

Acute pancreatic disease may be infectious or noninfectious. The proponents of the infectious theory point out the possibility of extension of infection along the lymphatics; by pyemic involvement via the blood stream; by direct contiguity; by extension along the pancreatic ducts from the duodenum or bile ducts; by activation by bacteria in the normal pancreas; or finally, by bacterial permeation from adjacent altered viscera.

In this connection, it may be of some interest to note that neither Truhart,[53] in 43 cases, nor Jones[30] found bacteria present in the pancreas. When we realize how infrequently acute pancreatitis is encountered in conjunction with perforation of duodenal or gastric ulcers into the pancreas, the rarity of the incidence of infection by contiguity becomes apparent.

Infection may be a potent factor indirectly. In late cases, the bacteria most frequently isolated are *E. Coli,* pneumococcus and staphylococcus. Brocq[8] cultured anaerobes from the gangrenous variety, but the necrotic type was sterile. Experimentally, Carnot,[10] and Korte[32] produced acute pancreatitis by injecting colon and pyocyaneus bacilli, and other bacteria into the pancreatic duct. Archibald[2] produced fatal pancreatitis by colon bacillus injection. Kemp[31] stated that certain bacteria, especially of the typhoid and colon groups, are capable of activating proteolytic pancreatic enzymes.

* Submitted for publication July, 1949.

Lymphogenous infection from the gallbladder, liver and appendix has been emphasized in both acute and chronic pancreatitis by Maugeret,[37] Arnsperger,[4] Deaver,[15] Graham[26] and others; but whereas most observers agree that this may be the modus operandi in the chronic type, the acute process has never been produced experimentally in this manner.

Jones[30] believes chronic pancreatitis to be the result of interstitial tissue inflammation produced by lymphatic extension, whereas acute pancreatitis involves the parenchyma via the pancreatic ducts.

Gastro-intestinal infection may reach the liver through the portal system and thence extend to the pancreatic gland.

Hematogenous pancreatitis through bacterial metastasis is rare, but pancreatic inflammation has been reported in conjunction with epidemic parotitis and infectious thrombophlebitic processes.

Rosenow,[47] experimentally, produced cholecystitis and pancreatitis by injecting intravenously streptococci obtained from the tonsils of patients with gallbladder symptoms.

The non-infectious theory presupposes first, mechanical stasis, and second, the chemical activation of inactive ferments resulting from autolysis of bile, duodenal contents or degenerated duct contents. Although associated biliary disease is a concomitant finding in the majority of cases, those without apparent cholecystitis must be explained. In these, toxic products may develop within the pancreas or may be regurgitated from the biliary tract or duodenum into the pancreatic ducts.

Inactive pancreatic juice is harmless. Experimental ligation of the pancreatic duct produces no necrosis. If, however, ligation be effected at the height of digestion, pancreatic necrosis ensues. Section of the duct, with escape of inactive juice into the peritoneal cavity, produces neither pancreatic involvement nor clinical symptoms. Simple pancreatic injury fails to produce necrosis, even though activating substance may be liberated.

Levin[33] crushed the pancreas when associated blood vessel occlusion existed and produced characteristic hemorrhagic necrosis. Clinically, trauma has frequently been followed by acute pancreatitis.

Bile for many years has been recognized as a factor in the production of acute pancreatitis. Bradley and Taylor[7] found that bile did not activate the enzymes. Others believe that bile merely accelerates the action of the pancreatic ferments. When bile was brought into contact with the pancreas, acute hemorrhagic pancreatitis resulted. It has been demonstrated that injection of small amounts of bile into the duct of Wirsung produces acute pancreatic disease, if done at the height of digestion. Opie[41] found that considerable amounts of bile were necessary. Nordmann[40] produced very little reaction with sterile bile, but infected bile was more potent in the production of pancreatic necrosis. Sodium taurocholate appears to be the offending substance. It is found in abundance in infected bile. Focal liver necrosis is noted early in acute pancreatitis.

According to the regurgitation theory, three factors are involved in the production of acute pancreatitis. First, a change in bile composition; second, undue resistance, such as is produced by stone or spasm; and third, elevation of gallbladder pressure or bile duct pressure sufficient to produce reflux of bile into the pancreas.

Clinically, bile may enter pancreatic ducts following obstruction of the common outlet in cases where bile and pancreatic ducts join, or by regurgitation of duodenal contents.

Here a few anatomical observations may not be amiss. Mann and Giardano[36] found that in only 3.5 per cent of subjects did the anatomic arrangement of bile and pancreatic ducts permit of common channel production. Cameron and Noble[9] concluded that in 75 per cent of individuals a calculus impacted at the papilla could produce a common passageway. It should be recalled that stones were found in the ampulla in but 5.4 per cent of 1287 cases, one of these the celebrated case of Opie, operated upon successfully by Halstead. It served, however, as an impetus to the study of pancreatitis.

Zuckerkandl[61] found that the accessory and main pancreatic ducts usually communicate by a wide opening, close to the duodenal end. Opie[41] found this situation in 90 of 100 dissections. Baldwin[5] found that the common duct opened separately into the duodenum in 25.8 per cent and in a common ampulla in 74.2 per cent.

Obstruction may be due to stone, spasm, inflammatory swelling, mucus, parasites, and even venous congestion due to cardiac decompensation. Spasm can be induced by dilute hydrochloric acid in the duodenum. It is also increased by gastroduodenitis and dietary indiscretion.

Duodenal contents in the absence of infection may produce acute pancreatitis. Polya[42] accomplished this by injecting small amounts of duodenal contents into the pancreatic duct. In support of the duodenal-origin hypothesis is a large number of cases where biliary disease is not apparent. Regurgitation may occur in acute or chronic dilatation, or aided by antiperistalsis, in the presence of a relaxed or dilated sphincter of Oddi.

Brocq[8] completely obstructed the duodenum following gastroenterostomy and produced pancreatic necrosis. Seidel[50] accomplished the same by causing stasis in the duodenum. Opie suggested the presence of delicate valves in the diverticulum of Vater, that normally prevent regurgitation.

Brocq suggested that predominance of the hemorrhagic feature in acute pancreatitis is the result of the activation of trypsin by regurgitated duodenal contents, while preponderant fat necrosis is due to bile regurgitation.

Substances that have been utilized to produce acute pancreatitis experimentally are diphtheria toxin, acid gastric juice, alkalies, calcium chloride, formaldehyde and leucocytes with bacteria.

Rich and Duff[45] have described a peculiar hyaline necrosis of the walls of the pancreatic arteries and veins in acute pancreatitis. They believed necrosis to be the initial lesion, and to be due to the extravasation of active trypsin.

They observed a remarkable metaplasia of the pancreatic duct epithelium in 13 of 24 cases examined, and since reflux of bile, infection and obstruction account for but two-thirds of the cases, they suggested that duct obstruction caused by this proliferation might be responsible for escape of trypsin, and consequently of hemorrhagic pancreatitis by thrombus and hemorrhagic production.

Inspissated secretion in the pancreatic ducts appears to be another cause. Acute pancreatitis may be encountered concomitant with degenerative pancreatic processes such as tumors, vascular degeneration, toxic changes in systemic disease, and trauma.

Clinically, acute pancreatitis is not a primary disease, but rather a complication or sequela. Whether we subscribe to one or another of the hypotheses, the realization that biliary disease is so frequently the etiologic precursor must be evident. Egdahl's[19] incidence of biliary calculi in 50 per cent and cholecystitis in 75 per cent is not mere coincidence. Where no biliary disease is apparent, it is well to recall Hess'[20] work. He produced acute pancreatic necrosis by ligating the pancreatic duct at the height of digestion. Pratt[43] did the same in fasting animals with no resultant necrosis. Notwithstanding all the possible methods of, and etiologic factors in the production of acute pancreatitis, we may assume the great majority to be due to biliary disease. Certainly these latter cases are those with which we are most frequently confronted.

Fat necrosis has been taken as the diagnostic criterion of the 154 cases herein analyzed. That acute pancreatitis does exist without fat necrosis has been proved clinically, but it was deemed advisable to include only those cases in which fat necrosis was demonstrable to prevent the possible inclusion of doubtful cases.

CLASSIFICATION

There is ample justification for considering acute edematous or interstitial pancreatitis as a milder grade of acute pancreatic necrosis, which may be predominantly hemorrhagic, necrotic or suppurative. Quick[44] operated upon a patient with edematous pancreatitis only to find two days later that she succumbed to extensive pancreatic necrosis as demonstrated at autopsy. Cole's[12] work offered corroboration by the finding, in six cases of acute pancreatic edema, of a sharp rise in blood amylase, a very significant observation in all forms of acute pancreatitis.

INCIDENCE

Seventy-six per cent of our cases involved females. The female-male ratio was the same in acute pancreatitis as in our cases of gallbladder disease, though Riese's[46] and Korte's[32] observations were to the contrary. The former observed males predominating, 79 to 42, the latter 30 to 14. If we regard biliary disease as the important etiologic factor, males and females are alike affected. Forty-five cases herein included occurred in a period during which

2049 cases of biliary disease were submitted to operation, an incidence of approximately 2 per cent.

Fifty per cent of our cases occurred in the fourth and fifth decades. The youngest patient was 19, the oldest 73.

Previous gastro-intestinal disorders are of considerable significance. All but 19 gave a history of some form of "dyspepsia" and of these, six had had repeated alimentary disturbances for three to four weeks prior to hospital admission. Sixty-three per cent gave a definite history of biliary disease.

Alcoholism, in the literature, constitutes one of the cogent factors in acute pancreatitis. When we realize that no case is permitted to enter our institution in which alcoholism is a predominating symptom, it becomes apparent why this series contains no case in which alcoholic diathesis plays any role.

PATHOGENESIS

Pancreatic symptomatology in its acute manifestations depends on the activation of trypsinogen into trypsin. Physiologically this activation occurs in the duodenum through stimulation by succus entericus. Protein digestion by this liberated enzyme may affect blood vessels, lymph structures or pancreatic cells. Activation is furthered by the products of cytolysis and by the calcium of extravasated blood serum. The liberated trypsin destroys protein molecules which have been combined with bile salts, thus setting the latter free to produce further cell damage. The resultant edema and sanguination may be extensive and severe in a very short time. If the process terminates at this stage, complete restitution may ensue. Progression may result in local or diffuse necrosis of the entire parenchyma.

Circulation of foreign protein in the form of incomplete protein digestion products may in part serve to explain the severe toxic picture. Some believe the significant product of proteolysis to be histamine, produced in the necrotic tissue or in the peritoneal fluid. Dragstedt[17] showed that intraperitoneal fluid and products of pancreatic autolysis, when injected, were not toxic. However, when these were infected, the characteristic symptoms developed. Experimental intravenous injection of peritoneal fluid from cases of acute pancreatitis by Cooke and Whipple,[13] was without toxic effect.

Blood vessel digestion contributes the hemorrhagic features. Peritonitis is due to toxic products circulating in the subserous lymphatics. Thus, the entire syndrome depicts a definite clinical entity that can be recognized.

Fat necrosis in acute pancreatitis may involve the fat of the abdominal wall, pericardium or pleura. The dissemination of this necrosis depends on the circulation of lipase in the blood. Wood[60] suggests that the activation of steapsinogen in the pancreas is by some constituent of the bile, and Flexner[24] demonstrated a fat splitting enzyme in necrotic foci. Splitting of a fat into soluble glycerin and fatty acid results in deposition of the latter as crystals, which later, with calcium, form globular masses surrounded by zones of round cell infiltration. Wells[57] found that a moderate amount of these necrotic areas might be absorbed in a week.

Digestion of pancreatic cells liberates their contained trypsin and lipase, and consequently not only these two enzymes, but the products of their complete and incomplete digestion as well, are circulated through the lymph channels. Therefore, symptoms of acute pancreatitis are due first to local pancreatic irritation, and second to the circulation of toxic products.

SYMPTOMS AND SIGNS

Pancreatic inflammatory reaction results in edema and swelling, with resultant stretching of the pancreatic capsule. This causes pain and obstructs diaphragmatic excursion. Bile drainage becomes impeded by common duct obstruction. Pressure on the abdominal brain, the celiac plexus, must be considered in the explanation of acute pancreatic symptomatology at least in so far as local manifestations are concerned.

Of all the symptoms, constant epigastric pain is most frequently encountered. This pain is splitting in character, "as though something within were boring its way through." The localization of pain in this series is shown in the accompanying Table I. Pain in acute pancreatitis is of intense severity. Morphine in repeated doses fails to relieve it. It is interesting to note that patients volunteer the information that a hypodermic injection has failed to ease their discomfort, whereas during previous attacks, relief had been immediate from one dose of narcotic.

Vomiting is a troublesome, persistent complaint. However, it is never progressive and never fecal. One gastric lavage usually suffices for relief, a differential feature from high intestinal obstruction. Coffee ground or bloody vomitus may occur, and is easily explicable when one considers the proximity of the stomach to the hemorrhagic pancreas.

Protein split products introduced into the circulation call forth a peculiar train of symptoms designated allergic or anaphylactic. At times these symptoms predominate. Shock, collapse, cyanosis, dyspnea, and in some instances, dermatologic reactions (urticaria) occur. The significance to the clinical picture of pressure on the celiac plexus can merely be mentioned, but Whipple[58] pointed out a peculiar asthenia characteristic of pancreatic disease. Cyanosis may in part be due to diaphragmatic embarrassment resulting from local pancreatic swelling.

Temperature plays little, if any, role in the diagnosis. Jaundice may be due to local pancreatic pressure on the ductus choledochus. It is never severe. Concomitant liver necrosis may influence the degree of jaundice, as will the presence of stones in the common duct. Acute yellow atrophy has been found as a complication of acute pancreatitis.

Peritonitis, whether bacterial or chemical in origin, produces the same symptoms, local or diffuse. Local peritonitis due to mechanical stretching of the peritoneum over the pancreas adds the local objective signs to the diffuse ones caused by the chemical irritant.

Constipation is not uncommon. Diarrhea, when it occurs, is usually a late manifestation indicating considerable pancreatic destruction. Constipation is

not complete, a fact of value in differentiating low intestinal obstruction. The silent paretic abdomen of acute pancreatitis offers a marked contrast to the abdominal findings in mechanical obstruction. Turner[54] described a bluish-brown discoloration of the skin overlying the left flank and back. This has never been seen by us. He also mentioned the diagnostic value of the para-umbilical skin discoloration, which was similarly lacking in our series (Cullen's sign).

Statistical resumés help but little in the diagnosis of acute pancreatitis. However, when a patient with a history of gallbladder disease presents a somewhat altered symptom complex, if morphine fails to alleviate the pain,

TABLE I.—*Pain in Acute Pancreatitis (154 Cases)*

Location	Percentage
Epigastric	87%
Right hypochondriac	61
Left hypochondriac	28
Left lumbar	54
General abdominal	30

which now radiates from epigastrium transversely to the left, if cyanosis and slight icterus, together with a peculiar asthenia and dyspnea occur, acute pancreatitis must be considered. Tenderness over the left hypochondrium and left costo-vertebral area should strengthen the clinical impression.

Tables I and II depict the location of pain and tenderness in our present series. In Table III, the more pertinent signs and symptoms, other than pain, are indicated.

TABLE II.—*Tenderness in Acute Pancreatitis (154 Cases)*

Location	Percentage
Epigastric	58%
Right hypochondriac	59
Left hypochondriac	30
Left costovertebral	37
General abdominal	26

DIFFERENTIAL DIAGNOSIS

Symptomatology must be clearly analyzed, for acute pancreatitis may simulate other acute abdominal entities. Acute empyematous cholecystitis may be troublesome in the differential diagnosis. This is especially true when impending perforation and local peritonitis exist. The presence of a palpable mass which attaches itself to the lower border of the liver aids greatly. Pear-shaped or globular, this mass denotes a distended gallbladder due to cystic duct block. Irregularity or bogginess of the mass may be caused by adherent omentum protecting an impending blow-out, or an already perforated gallbladder. Because of its superficial position, light palpation performed by placing the

palm of the hand on the abdomen with the patient breathing slowly and deeply, easily discloses the mass. It is significant that only 7 per cent of our cases of acute pancreatitis had acute cholecystitis at the same time.

Perforation of a diseased gallbladder into the general peritoneal cavity produces shock simulating that of acute pancreatitis, but the differential diagnosis may be made by the history of a previously distended, acutely inflamed gallbladder, where medical treatment failed to relieve the cystic duct block. Gallbladders do perforate, but if the sudden onset of acute pancreatitis is borne in mind, and the local findings enumerated above are absent, a correct diagnosis can be made.

Acute intestinal obstruction, especially the high variety, may offer some difficulty. Although the shock produced by the sudden snaring of a loop of gut by a band or internal hernia may be great, the early visible peristalsis, the progressive vomiting, the painless abdomen, the absence of epigastric and left costovertebral tenderness and the absent malar flush, all assist in making a correct diagnosis.

TABLE III.—*Other Symptomatology (154 Cases)*

	Percentage
Cyanosis	45%
Shock	17
Emesis	88
Abdominal distention	56
Jaundice	27
Urticaria	3

Left renal colic, particularly when attended by extreme pain and shock, offers some difficulty. If radiation of pain to the groin is absent, acute pancreatitis must be considered. Pyuria or the presence of erythrocytes in the urine certainly help. Sudden torsion of a ptotic kidney with renal pedicle strangulation simulates pancreatitis. The history of ptosis in a patient with considerable weight loss and the picture of Dietl's crisis following sudden exertion supports the diagnosis. The kidney may be readily felt, and found enlarged and tender, if it is palpated in the lumbar region. If it is displaced to the midline its mobility can be demonstrated, and it may be reposited in the lumbar fossa.

Tenderness in the left inguinal region, a definite Head zone, is not infrequent in acute pancreatitis, particularly when considerable bloody fluid is present in the peritoneal cavity.

Acute carbunculosis of the left kidney calls for discriminatory analysis. Here, the antecedent history of some focal infection, coupled with sudden onset of chill, rise in temperature, tenderness and spasticity in either lumbar region, occurring in an otherwise healthy individual, even in the absence of pertinent urinary findings, are differential characteristics. If the anterior surface of the nephros is the site of adhesions to the parietal peritoneum, there may be added

confusion with acute pancreatitis. However, the toxemia, the shock, the flush, the paretic abdomen and the characteristic epigastric tenderness are missing.

Perforated peptic ulcer with its antecedent ulcer history, board-like rigidity and scaphoid abdomen, may well be distinguished from the pancreatic paretic abdomen. The absent mid-epigastric tenderness, the early signs of spreading peritonitis, the obliteration of liver dullness, with roentgen ray evidence of air under the diaphragm, the expiratory grunt and the absent malar flush exclude pancreatitis. The ulcer patient usually presents a characteristic facies, the long, thin, drawn, dyspeptic countenance portraying chronic pain.

Coronary and cardiac disease demand consideration. Careful precordial examination is essential, for the manifestations of heart disease are protean, and they may well simulate intra-abdominal catastrophes. A pre-existing cardiac history, with liver tenderness due to right coronary closure, upper abdominal rigidity, and an extremely hypersensitive abdominal wall, will lead to the correct diagnosis.

Acute appendicitis should give no difficulty, even when spreading peritonitis is present.

LABORATORY AIDS

What are the laboratory aids that may be utilized? The total and differential leucocyte counts of the blood are of little value. In fact, it may be stated that the importance of the white cell count in acute abdominal conditions is probably over-emphasized. Infection, hemorrhage, shock, and dehydration influence it. It should be used merely as corroborative evidence. Acute abdominal pain produces leucocytosis.

The erythrocyte count is usually high, over 5 million. Hemoglobin content, too, is elevated because of the dehydration. Increased hemoglobin may be utilized as an index of the severity of shock, and should considerably influence the surgeon as to the advisability of immediate operative intervention. Serial determinations should be made frequently in order to determine the necessary fluid requirements for the restoration and maintenance of normal blood volume.

Blood enzyme determinations should be performed early, and frequently repeated. The serum amylase test is of great value (especially early in the disease). Its determination can be carried out rapidly, and elevation of amylase levels occurs early. The lipase determination has greatest value after the first 48 hours of the illness, and its concentration remains elevated for a longer time than that of the amylase, since the latter enzyme is excreted from the body quite rapidly. Determinations for both these enzymes when acute pancreatitis is suspected should be urgently requested. There is a definite relationship between amylase findings and clinical progress. Normal determinations may re-appear within a few days in a mild attack. Normal values indicate little or no pancreatic destruction. Following cholecystostomy, the blood amylase values in pancreatic disease return to normal rather abruptly, because of relief of pancreatic pressure. Similar subsidence may occur when

pancreatic necrosis is progressive. Here, destruction of parenchyma which is the source of the hyperenzymemia, prevents manufacture and liberation of the pancreatic enzymes. Hyper-cholesterolemia has been frequently reported.

The urine may manifest the intoxication by the presence of albumin and casts. Glycosuria need not be, and usually is not present. Any severe peritonitis may be accompanied by glycosuria. Urinary diastase may rise from the normal of 30 units to 200–1000.

Recently, Edmondson and Berne[18] have drawn attention to the marked mobilization of calcium in and around the pancreas resulting from the formation of calcium soaps which are clinically recognized as the areas of "fat necrosis." This results in an absolute hypocalcemia which is most apparent between the fourth and tenth days of the disease. Fatal prognostic significance has been attached by them to serum calcium levels below 7 mg. per 100 cc. Early serum calcium determination has little value in the diagnosis of acute pancreatitis; or where fat necrosis is very minimal.

A scout film of the abdomen may show free air under the diaphragm or fluid levels in intestinal loops, indicating perforated ulcer or acute intestinal obstruction respectively. Later, if the patient's condition permits, a barium meal may disclose a wide duodenal sweep, an irregular greater curvature of the stomach, pyloric obstruction, or a depressed transverse colon, all signs of an enlarged pancreas.

Gottesman and his associates,[25] and more recently, Bockus and Raffensperger[6] have described significant electrocardiographic changes in acute pancreatitis. Improvement in the patient's clinical status is concomitant with the disappearance of these abnormal tracings. Hypopotassemia occurring in association with vomiting and/or dehydration has been ascribed as the cause for these changes by Bockus, quoting Bellet.

TREATMENT

During the past decade, therapy of acute pancreatitis has tended toward conservatism. Surgery is usually either delayed or withheld entirely. Immediate operation is justified only when the diagnosis is uncertain, when peritonitis is marked, when ileus persists without improvement, or when abscess is present. Subsequent operative intervention may be contemplated following the acute phase, especially when cholecystitis is the precursor (as it has been in practically all our cases).

If we have, with a fair degree of certainty, established the diagnosis of acute pancreatitis clinically, immediate surgical intervention avails us naught, and the added trauma may act to the detriment of the patient. The therapy should be directed to stopping the activation of trypsin within the pancreas, for, regardless of whether we believe that the mortality in acute pancreatitis results from shock, anaphylaxis, or toxemia, the basic mechanism in the evolution of the pathologic and the clinical picture is parenteral tryptic digestion. If perforated ulcer and intestinal obstruction can be definitely excluded, conservatism directed towards halting trypsin digestion is indicated.

MEDICAL REGIME

The principles of treatment which are generally employed include: starvation, which markedly inhibits the secretion of tryptic ferments; continuous gastric suction, to further rest the pancreas; the relief of pain by means of opiates and by procaine injection of the splanchnic nerves; the restoration of normal blood concentration and volume, utilizing whole blood, plasma and glucose (the latter to be given with sufficient insulin "coverage" to prevent pancreatic stimulation); the prevention of distention by Miller-Abbott intubation; the inhibition of nervous stimulation of the pancreas, using atropine and ephedrine; and the recognition and elimination of hypocalcemia, utilizing calcium gluconate parenterally. Recently roentgen ray therapy has been used successfully by Chisholm and Seibel[11] to decrease the serum amylase in acute pancreatitis in experimental animals, and also in a small series of clinical cases.

SURGICAL TREATMENT

Surgically, five procedures have been developed as follows:

1. *Pancreatic drainage,* by splitting the peritoneal covering of the pancreas or by section of the gland itself, to encourage external discharge of the necrotic material. The process in the pancreas is not ameliorated by such manipulation and pancreatic incision may enhance the danger of hemorrhage. A fatal result was reported by Walzel[55] due to trauma to the splenic vein. Besides, the anatomic arrangement of the pancreas into lobules precludes complete drainage unless each lobule be split. Operative handling of the pancreas serves no good purpose, but on the contrary, may destroy natural protective barriers.

2. *Lesser sac drainage* to prevent toxic product accumulation and forestall pseudocyst formation. Smead[51] has demonstrated that the dilution and neutralization of these substances by blood and exudate is so complete that they are not harmful and removal is unnecessary.

3. *Cholecystostomy* to decompress the entire biliary tract. This procedure is less hazardous than common duct drainage with or without gallbladder excision. However, pancreatitis does recur after gallbladder drainage, as does the pre-existent cholecystitis. At times, emergency cholecystostomy must be done.

4. *Choledochostomy,* although more efficacious, can have no rational indication, except in the presence of jaundice due to stone, or dilated ductus choledochus.

5. *Cholecystectomy,* although it can accomplish the removal of the underlying cause, may add too much trauma to an already shocked patient. Too frequently have renewed attacks of acute pancreatitis followed immediately after this procedure, and too often have pancreatic pseudocysts resulted. Cholecystectomy is followed either by dilatation of the common duct with a continent sphincter of Oddi, or the sphincter too may dilate, with resultant incontinence. These events require time, and before such sphincter relaxation ensues, spasm may lead to pancreatic necrosis. Disturbed innervation results

in common duct and sphincter relaxation. Unless this sphincteric atony occurs, increased biliary pressure results, and continues until either the ducts distend or the sphincter dilates. This primary increase in pressure predisposes to acute pancreatitis. Rost[48] reported a fatality in acute pancreatitis following instrumental dilatation of the sphincter at operation.

Halstead,[28] in 1890, successfully operated on acute pancreatitis, merely establishing the diagnosis at celiotomy. He closed the abdomen without drainage of the peritoneal cavity. Halstead, again in 1901, unsuccessfully operated

TABLE IV.—*Operative Findings in 154 Cases*

	Percentage
Fat necrosis	100%
Gall bladder disease	81
Calculi	54
Beef broth fluid	55
Granular omentum	29
Acute cholecystitis	23

upon Opie's case of stone impacted at the ampulla of Vater. Von Haberer,[27] in 1909, advocated routine cholecystostomy to provide a drainage vent, but he presupposed ampullar block in all cases. It thus becomes fairly well established that splitting the capsule and pancreatic drainage do not influence the pancreatic process for recovery and certainly in the severer cases, cholecystectomy and choledochostomy will not be tolerated.

TABLE V.—*Operative Procedures in 154 Cases With Mortality Rates*

	Cases	Deaths	Percentage
Cholecystectomy	30	2	6.6%
Cholecystostomy	83	20	24.0
Choledochostomy	2	0	0.0
Choledochostomy with cholecystectomy	10	0	0.0
Pancreatic drainage	23	14	60.8
Exploratory laparotomy	4	1	25.0
Incision and drainage of lesser sac	1	0	0.0
Multiple operations in the acute phase			
A—Pancreatic drainage followed by			
B—Cholecystostomy	1	0	0.0
Total	154	37	24.0

Korte,[32] Abell,[1] Eggers,[20] Wolfer,[59] McWhorter[39] and Jones[30] have advocated immediate intervention. Wangensteen,[56] Smead,[51] Lewis,[34] Mikkelsen,[38] De Takats and MacKenzie[52] indicated a preference for early conservatism followed by subsequent biliary tract operation.

Eliason and North,[21] although advocating early operation, conclude that emergency operation may not be best. McWhorter,[39] who believes early operation the procedure of choice, observed the lowest mortality rates in the deferred operative group.

Mortality rates of 50 per cent to 70 per cent are reported by many observers. Mikkelsen[38] by delaying operative intervention from one to three weeks reduced his mortality to 7.5 per cent in 39 cases, 20 of whom were very ill. Demel,[16] from 1926 to 1934, operated upon 95 per cent of his 22 cases immediately, lost 78.3 per cent. In the next 34 cases, but 50 per cent were operated upon immediately, with 26.4 per cent succumbing.

During the past ten years, cholecystectomy has been our operation of choice, if performed one week to ten days after subsidence of acute symptomatology. Ligation of the cystic duct, however, has been purposely omitted. A soft rubber tube is placed over the cystic duct stump, thereby establishing a vent for biliary drainage should sphincteric spasm with possible recurrent acute pancreatitis ensue. In effect, choledochostomy without its additional trauma and shock is accomplished, with decompression of the biliary system and concomitant removal of the focus of infection.

Placing a drainage tube within the cystic duct would accomplish the same result, but with this difference: if subsequent spasm did not occur, convalescence would be unduly delayed by persistent biliary drainage. By placing the tube over the cystic duct, closure of this duct progresses without interference. The danger of biliary peritonitis need give us no concern. We have practiced this mode of treatment for the past ten years with happy results.

Further analysis of the 154 cases will be found in the accompanying tables.

SUMMARY

The pathogenesis of acute pancreatitis has been presented.

Differential diagnosis has been discussed with especial emphasis on acute intestinal obstruction and perforated ulcer.

The immediate operative and conservative forms of therapy have been compared.

Our present mode of delayed operation has been described.

There remains but one further thought, and that is to urge the necessity for removing the principal offending organ before the complication of recurrent acute pancreatitis presents itself.

The authors wish to thank those surgeons whose cases were used in the preparation of this paper.

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INTRATHORACIC PHEOCHROMOCYTOMA WITH HYPERTENSION*

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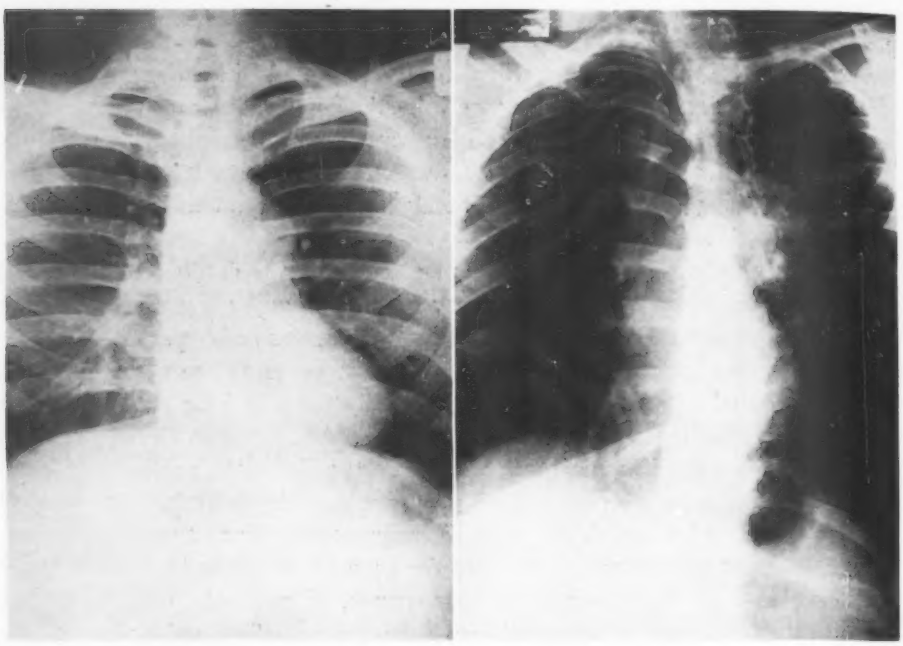
A PHEOCHROMOCYTOMA usually occurs in or near the adrenal glands but may occasionally be found in other parts of the chromaffin system. The tumor derives its name from the fact that the cytoplasm of the component cells contains a reddish-brown pigment when the tissue is fixed in chromate solution. These characteristic cells may produce epinephrine and thus cause paroxysmal or persistent hypertension. A case of intrathoracic pheochromocytoma with hypertension in which the tumor was successfully removed by operation is presented in this paper. The extra-adrenal pheochromocytomas reported in the literature are briefly analyzed.

Although only a very small percentage of cases of high blood pressure are caused by an adrenalin-producing tumor of the chromaffin system, this lesion should always be considered in the differential diagnosis of hypertension. The blood pressure elevations caused by a pheochromocytoma are not necessarily of a paroxysmal type. In some cases, especially those of long standing, there is persistent hypertension with little fluctuation. According to Green's review[8] of 51 cases of pheochromocytoma with hypertension, only 14 had a normal blood pressure between paroxysmal elevations, while the other 37 patients constantly showed some elevation of blood pressure. Since the pheochromocytoma was removed surgically in 12 of the 14 cases which had a normal blood pressure between the hypertensive paroxysms, it can only be conjectured whether these patients, if untreated, would have eventually developed sustained elevations in blood pressure as has been suggested by Wells and Boman.[25] Some pheochromocytomas apparently produce no adrenalin and therefore do not cause hypertension.

According to Kohn[11] chromaffin cells can be found along the entire length of the autonomic nervous system, and occur in nests in the autonomic ganglia. Some authors employ the term "paraganglioma" for the extra-adrenal chromaffin tumors arising in the paraganglia. Most of the extra-adrenal pheochromocytomas that have been reported have been found in retroperitoneal portions of the abdomen, usually near the kidneys or in the aortic bodies or organs of Zuckerkandl which are located on either side of the aorta at the origin of the inferior mesenteric artery. Although the carotid body is a part of the chromaffin system, no adrenalin-producing tumor in this region is on record. However, a case of carotid body tumor, which contained no pressor substance, and concurrent pheochromocytomas of both Zuckerkandl bodies has been reported.[3]

* Submitted for publication December, 1948.

Intrathoracic pheochromocytomas are extremely rare. To date, only two such tumors, diagnosed at autopsy, have been reported. Only one of these was known to have caused hypertension. The case reported here is apparently the first in which a diagnosis of intrathoracic pheochromocytoma with hypertension was made during life. The true nature of the lesion was suspected prior to operation because this young man had both an unexplained hypertension and an intrathoracic tumor in the region of the sympathetic chain in the costovertebral area.



A B

FIG. 1.—A. Posteroanterior roentgenogram of chest shows a small rounded mass projecting from the mediastinal shadows just below the arch of the aorta.

B. Oblique view shows mass in left costovertebral region extending from the fifth to the seventh ribs.

CASE REPORT

V. K., male, age 25 years, entered the army when he was 22 years old and at that time he had a normal blood pressure. Later, while in service, hypertension was discovered. During the course of a diagnostic study, a roentgenogram of the chest revealed a small tumor mass in the left costovertebral area just below the level of the arch of the aorta. Re-examination of the induction film showed that the shadow had been present at that time. After a thorough investigation, a diagnosis of essential hypertension and neurofibroma of the costovertebral area was made. The patient complained of easy fatigue, increasing nervousness, palpitation, slight dyspnea, occasional dizziness, headaches and sweating of the hands. No pulmonary symptoms were present. Physical examination revealed a well developed and well nourished male. There was considerable moisture of the palms of the hands. The systolic blood pressure varied between 190 and 210 mm. Hg.

and the diastolic pressure between 100 and 120 mm. Hg. The physical examination was otherwise negative. Roentgen studies at this time (Fig. 1) revealed that no appreciable change in the size of the mass had occurred in a two and a half year period.

Operation was performed on November 2, 1945, under ether-oxygen intratracheal anesthesia. Because an intrathoracic pheochromocytoma was suspected, blood pressure readings were taken every five minutes during the operation, and adrenalin was ready for immediate injection. Through a posterolateral transpleural incision on the left side, the tumor was exposed. A purplish-red mass measuring 5 by 4 by 5 cm. was found in the

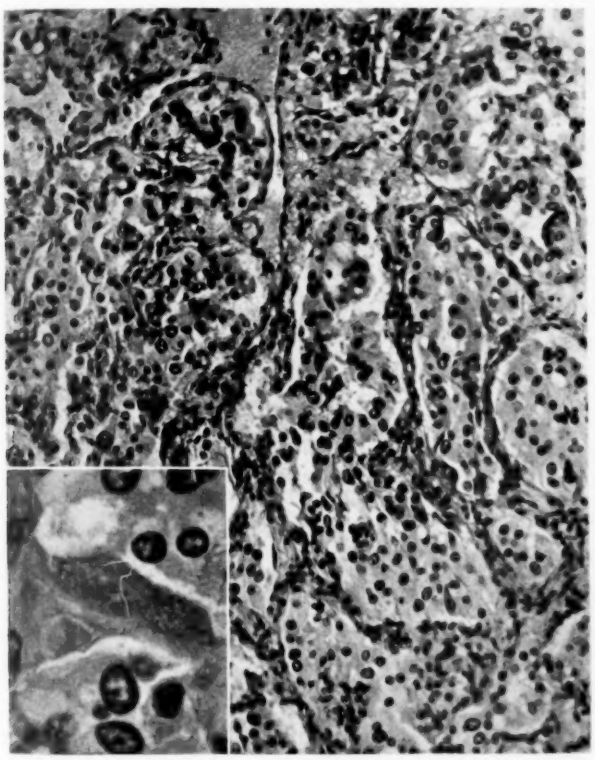


FIG. 2.—Photomicrograph of pheochromocytoma. The characteristic arrangement of tumor cells in lobules separated by capillaries is shown (x 150). Insert shows chromaphilia granules (x 640).

costovertebral area just lateral to the upper portion of the descending aorta. The mass rested on the ribs and intercostal structures in the costovertebral groove. It was covered by pleura, was fairly well encapsulated and was soft in consistency. The sympathetic nerve trunk traversed the mass. The appearance and consistency of the tumor was more that of a glandular structure than that of a neurofibroma. Care was taken to minimize manipulation of the tumor during the freeing of the mass in order to avoid a hypertensive crisis. Within five minutes of clamping the blood vessels leading to the tumor, the systolic blood pressure dropped from 220 to 110 mm. Hg. and a few minutes later was barely obtainable. Intravenous adrenalin was given and a gradual elevation of the blood pressure occurred. Aside from the dramatic change in blood pressure, the patient's condition appeared satisfactory. The blood pressure was within a normal range throughout

the first postoperative day, but on the second day the systolic pressure rose to about 160 mm. Hg. where it remained. The postoperative course was otherwise uneventful.

The pathologic specimen consisted of an oval mass of tissue weighing 28 Gm. The surface was deep red and one portion was covered by a grayish-white membrane. Microscopic examination revealed a neoplasm which was made up of small or medium sized nests of tumor cells separated from each other by a relatively scanty stroma rich in congested capillaries. The tumor cells were medium sized and oval, polyhedral or irregular in shape, with a fair amount of pale staining vacuolated or finely granular cytoplasm and eccentrically placed, generally round, compact nuclei. Several syncytial masses, resembling irregular giant cells were observed. A few mitotic figures were noted. The tumor was fairly well circumscribed by a capsulelike layer of connective tissue. It presented many small areas of hemorrhage and here and there were clumps of brown pigment. The pathologic diagnosis was pheochromocytoma (Fig. 2).

Because the blood pressure was still somewhat elevated, perirenal air studies were done by Dr. George Cahill in March, 1946, but no evidence of a tumor in the adrenal region was found. The patient also had a test performed with a benzodioxan derivative.[6] A drop in the blood pressure upon the injection of this adrenalitic substance is known to occur in cases of pheochromocytoma. No change in blood pressure was recorded in this patient. The test suggested that no further adrenaline-producing tumor tissue remained.

During the first two years following operation the blood pressure ranged between 160 to 180 systolic and 100 to 110 diastolic. The feeling of weakness and the other symptoms which were present prior to operation disappeared although some nervousness remained. Two and a half years after operation the blood pressure was 140/80 mm. Hg. The patient was feeling well and leading a normal active life three years postoperatively.

DISCUSSION

In about 12 per cent of the cases of pheochromocytoma recorded in the literature, the tumor was located outside of the adrenal area. An analysis of these 19 cases of extra-adrenal pheochromocytoma[1-5, 7, 9, 10, 12-14, 16-21, 23] reveals that the sex distribution is approximately equal. Although the age of the patients varied widely, over one half were less than 40 years old. The tumor may occur in childhood. In several instances an operation had been undertaken because of the presence of an abdominal mass, but a correct preoperative diagnosis was rarely made. In over one half of the recorded cases the tumor was an unexpected finding at autopsy. In some instances the cause of death was unrelated to the tumor, but in several cases signs of arteriosclerosis were present at postmortem examination. This finding is significant as the majority of these patients were under 40 years of age. Hypertension was known to have been present in a few cases, but most of the reports of extra-adrenal pheochromocytomas either deny hypertension or fail to record the blood pressure. One patient, admitted to the hospital in a critical condition, showed a hypotension until death a few days later; autopsy in that case revealed a hemorrhage into a retroperitoneal pheochromocytoma.[5]

The first intrathoracic pheochromocytoma, an incidental finding at autopsy in a 39-year-old female, was reported by Miller[17] in 1924. The tumor was in the right costovertebral area at the level of the sixth rib, and was about the size of two walnuts. The report did not state whether the patient had had hypertension.

The second intrathoracic pheochromocytoma diagnosed at autopsy was reported by Philips[19] in 1940. This man was 39 years old at the time of death, but was known to have had hypertension since the age of 29 years. He complained of episodes of cardiac palpitation and throbbing in his head, as well as some dyspnea, polyuria and nocturia. At 33 years of age he experienced a left hemiplegia. The heart was enlarged and the blood pressure varied between 170 mm. Hg. and 220 mm. Hg. systolic; while the diastolic pressure was about 120 mm. Hg. Roentgenographic examination of the chest showed a mass at the left apex posteriorly, which did not move on swallowing and did not compress the trachea. The patient also had a Horner's syndrome on the left side. Six years later the patient had an acute coronary occlusion and died in congestive heart failure. At autopsy a firm mass about the size of a plum was found at the apex of the left pleural cavity. The mass was not attached to the lung and was easily shelled out. In addition to the tumor, the autopsy revealed myocardial infarction and marked arteriosclerosis of the coronary arteries, aorta and renal vessels.

Wahl and Robinson[24] reported a case of neuroblastoma of the mediastinum with pheochromoblastomatous elements. The patient, a four-year-old boy, died of a neuroblastoma in the upper posterior thoracic region which had metastasized diffusely. Microscopic examination of the primary tumor revealed a sympathogonioma with mixed neuroblastic and pheochoromoblastic elements. Transition could be seen between primitive nerve cells and the chromaffin cells. The metastases were all of the embryonic neuroblastomatous type whereas the differentiated elements were present only in the primary growth. The child's blood pressure was not mentioned.

Pheochromocytomas may be multiple. In approximately 15 per cent of adrenal pheochromocytomas the tumor is bilateral. Occasionally one tumor may be in the adrenal region and a second one in the organs of Zuckerkandl or in some other retroperitoneal region. The number of extra-adrenal pheochromocytomas that have been reported are too small to justify an opinion as to whether or not the likelihood of multiple pheochromocytomas is greater when one of the tumors is located outside the adrenal region. It is only during the past few years that cases with coexisting intra-adrenal and extra-adrenal pheochromocytomas have been cured by surgical excision. The two previously reported intrathoracic pheochromocytomas were solitary tumors found at autopsy. In my patient the persistence of some hypertension for a considerable time postoperatively raised the question at that time whether another pheochromocytoma might be present, but laboratory tests and the later clinical course did not support this supposition.

The association of pheochromocytomas and neurofibromatosis is significant.[22] When both types of tumors are present, the pheochromocytoma might clinically be mistaken for another neurofibroma.

A small number of malignant pheochromocytomas have been reported. Apparently hypertension has not been present in the malignant cases. This is

not surprising when one bears in mind the fact that the production of adrenaline requires a marked degree of cell differentiation and cancer is more frequently found in undifferentiated cells. The cases of malignant pheochromocytomas have shown bilateral adrenal involvement. The metastases may be widespread.

The symptoms presented by some patients with a pheochromocytoma can easily be confused with hyperthyroidism. Nervousness, sweating, intolerance of heat, weight loss in spite of good appetite, easy fatigue and palpitations may be present. In some such cases of pheochromocytoma the basal metabolic rate may be considerably elevated due to hypermetabolism.[15]

Surgical removal of a pheochromocytoma usually causes the blood pressure to return to normal levels. This correction of hypertension may even occur in some cases with preoperative disturbance in renal function and hypertensive retinitis, but it must be assumed that in some advanced cases the changes will be irreversible.

Since the hypertension in cases of pheochromocytoma is due to circulating epinephrine, adrenolytic drugs have been studied as a test for this lesion. Goldenberg *et al*[6] report that some benzodioxanes injected intravenously cause a transient drop in blood pressure in patients with hypertension produced by a pheochromocytoma, whereas no drop in blood pressure occurs when a similar test is applied to other cases of hypertension.

CONCLUSIONS

The diagnosis of intrathoracic pheochromocytoma should be considered when a tumor in the costovertebral portion of the chest is associated with paroxysmal or sustained hypertension, especially in the younger age group. Roentgenograms of the chest are indicated in all patients with symptoms and signs suggestive of excess circulating epinephrine. Pheochromocytoma is added to the list of intrathoracic tumors requiring surgical excision.

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SPONTANEOUS RUPTURE OF THE ESOPHAGUS

REPORT OF TWO CASES: ONE WITH RECOVERY AFTER SURGICAL REPAIR*

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SPONTANEOUS RUPTURE of the esophagus is a rare, and from previous reports apparently a universally fatal accident. Excellent reviews have been furnished by Fitz,[9] Walker,[23] Klein and Grossmann[16] and more recently by Eliason and Welty[8] and Barrett.[2A] In 1946, Eliason and Welty[8] stated that 41 cases had been recorded. They added three more cases, the mortality of the 44 cases being 100 per cent.

Since their report, at least ten[2A, 10, 15, 20, 24] additional proved fatal cases have been recorded, making a total of 54 cases with a 100 per cent mortality. The ten recent cases will be reviewed briefly.

In 1946, Barrett[2A] reported three cases of spontaneous perforation, one of which was proved to be a rupture. The patient, a 45-year-old male, had sudden onset of back pain after a short prodromal period of malaise, and collapse developed rapidly. Because of predominantly abdominal signs, a diagnosis of perforated ulcer was made and abdominal exploration performed. He succumbed 24 hours after operation and 26 hours after the onset of the acute illness. At postmortem, the esophageal rent was ½ inch long and was located 2½ inches above the diaphragm.

Foggitt[10] reported the case of a 55-year-old woman in whom the diagnosis was made preoperatively by a barium swallow. The rent in the esophagus was repaired by the abdominal approach, with death resulting two days after admission.

Weder,[24] in 1943, reported a case of rupture which might not be considered truly spontaneous since the patient was known to have a stricture, and the rupture followed forced swallowing of a large piece of meat impacted in the stricture. However, the rupture occurred in the normal esophagus well below the stricture. The patient died 46 hours after the rupture despite drainage of the neck and pleural cavity. The esophageal rent at postmortem was 6 cm. long.

Pembleton[20] in 1947 reported briefly a case of esophageal rupture secondary to indirect trauma, when a weapons carrier fell over on the patient, a soldier. This patient had a severe tension pneumothorax, due to the ruptured esophagus which was the cause of death nine hours after injury.

Other cases previously recorded, secondary to trauma, were those of Aldrich and Anspach,[1] Griffith[13] and Murdoch.[19]

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McLeod and Gardner[17] reported the case of a 58-year-old male who had been on an ulcer regimen for gastric ulcer. He suddenly developed epigastric pain with vomiting and rapid onset of shock. With the diagnosis of perforated ulcer, an abdominal exploration was carried out. No intra-abdominal lesion was found and he succumbed 25 hours after the onset. At postmortem examination 1800 cc. of coffee ground material were found in the left pleural cavity with a longitudinal rent 3.5 cm. long on the postero-lateral wall of the esophagus.

Most recently, Kinsella *et al.*[15] reported five cases with a mortality of 100 per cent, although one death cannot be ascribed to the disease itself.

Perforation, as distinguished from rupture of the esophagus, is more common, especially that secondary to foreign body, stricture or instrumentation. Reported cures of these cases are not uncommon. Even cases of perforated peptic ulcer of the esophagus, which may at times be painless and so seemingly spontaneous, are not so rare, and at least one such case has been cured by pleural drainage (Benson and Penberthy[3]). Barrett[2A] in his excellent review included cases of both spontaneous rupture and perforation.

Several cases of spontaneous perforation have been reported recently, including those of Casper[4] and Culver and Clark.[6] Several cases in which it is difficult to determine the exact pathology, whether perforation or rupture, have been reported. These have been cases which have survived for a long time on conservative treatment and then have had pleural drainage with the diagnosis being made by passage of swallowed fluid or food. The patients of Frink[11] and Moore and Murphy,[18] both of whom recovered, fall into this category. A similar case, seen in this hospital, is being reported in detail by Dr. Paul Vestal. Still another case was recorded briefly in a general discussion by Cummings.[7]

Of the 54 cases of proved spontaneous rupture reviewed, eight[5, 8, 10, 12, 15, 21, 23] were diagnosed preoperatively or premortem and only three received definitive surgical treatment,[5, 10, 15] the third being Case 5 of Kinsella *et al.* Many cases, of course, were seen before the day of thoracic surgery. The first case to be diagnosed and treated surgically was that of Collis *et al.*[5] Their case was diagnosed by the presence of subcutaneous emphysema in the neck and confirmed by barium swallow. Exploration was carried out through the chest and the esophageal rent was closed, but the patient unfortunately succumbed.

Foggitt[10] explored the distal esophagus through the abdomen after making the diagnosis in a similar manner. The rent was closed after pulling the esophagus down into the abdomen. A gastrostomy was made at the same time, but despite this the patient succumbed 48 hours after the onset.

Kinsella[15] made the diagnosis in Case 5 of their group of cases; this was confirmed by barium swallow, and eight and one-half hours after the rupture, operation was performed. The patient was doing well on the eighth postoperative day when he succumbed to a pulmonary embolus.

More recently a case of perforation of the esophagus has been treated surgically by Barrett[2B] with survival. The patient, a female, was explored through the chest seven hours after the onset which occurred in the late convalescence from a pelvic operation. A tiny perforation was found 1½ cm. above the diaphragm, closed with a purse string suture and the area drained. A leak developed on the eighth day, and was followed by formation of a mediastinal abscess, which required drainage. A lung abscess developed in the R. U. L. which drained spontaneously through the bronchus. Three months after the operation the patient was well.

Two cases treated at New Haven Hospital are the subject of this report: the first, a case of rupture diagnosed and treated successfully by surgery; the second, a fatal case of rupture diagnosed incorrectly. A third case, diagnosed as spontaneous perforation of the esophagus and treated by laparotomy with survival after late diagnosis and thoracotomy drainage, is being reported in detail by Dr. Vestal. Only Case No. 1 was seen by the author.

Case 1. W. S., N. H. H. No. B34078, a male Negro of 35 years, was admitted to the Emergency Room of N. H. H. at 6:30 A.M., August 9, 1948, complaining of severe high epigastric and substernal pain. The diagnosis of the admitting intern was renal calculus or perforated duodenal ulcer. Roentgenograms of the abdomen revealed no gross abnormalities. The patient was then seen by the surgical resident on call (Dr. Krementz) who noted subcutaneous emphysema in the neck and made a tentative diagnosis of perforated ulcer of the esophagus.

At 3:00 A.M. the patient had been awakened by substernal and epigastric discomfort with a sense of fullness and a great thirst. He rose, obtained ice water and drank three glasses very quickly. Following this, he was seized by agonizing substernal and epigastric pain. Almost immediately he became nauseated, retched and vomited a "cup full" of bright red blood. The pain, nausea, retching and vomiting persisted. Within about an hour, the pain radiated around the costal margin and then up to the left shoulder. About the same time he noted respiratory difficulty with pleuritic pain. He then was brought to the hospital.

The past history was obtained piece-meal, with some discrepancies. The patient stated that he had had for over ten years rare attacks of epigastric fullness with substernal discomfort. These attacks were always relieved by taking water, or food. There was some question of his having had tarry stools immediately before the onset of the present illness. Although the patient denied it on admission, the history was eventually obtained that he had been on an alcoholic spree the weekend before the onset of the present illness.

Examination revealed a well-developed and extremely apprehensive Negro obviously in acute distress, with pulse ranging from 100 to 140, respirations 40, temperature 101° and B. P. 110/70. There was easily palpable subcutaneous emphysema in the neck. The respirations were very shallow and the patient could not be persuaded to take deep breaths. There were no changes in percussion noted but definite diminution of breath sounds particularly over the lower left chest. The abdomen was rounded and there was tenderness, moderate spasm and rebound tenderness over the epigastrium. The remainder of the examination was unremarkable. Laboratory studies: RBC 3,070,000; WBC 11,500 with 90 per cent polys; Urine 7–15 WBC, Plasma protein 5.95, Chlorides 111.6, NPN 29.

Roentgenograms of the chest revealed mediastinal emphysema on the left and interstitial emphysema in the neck plus a questionable small pleural effusion on the left. A lipiodol contrast study of the esophagus, using 15 cc., revealed a normal esophageal pat-

tern, but with an extravasation of a large quantity (about 1/3 of the dye) into the mediastinal soft tissues to the left and posteriorly (Fig. 1).

The patient was given penicillin, intravenous sodium sulphadiazine and infusions. His pain persisted with slight relief from morphine, and he developed clinical signs of fluid in the left pleural cavity and increasing signs of peritoneal irritation. It was decided that the best chance of cure was with operation. A Levine tube was passed into the stomach with ease. At 12:00 noon he was taken to the operating room at which time his pulse was 140, respirations 40 and blood pressure 97/40. Endotracheal anesthesia followed sodium pentothal induction, supplemented by cyclopropane and ether with a small amount of curare.

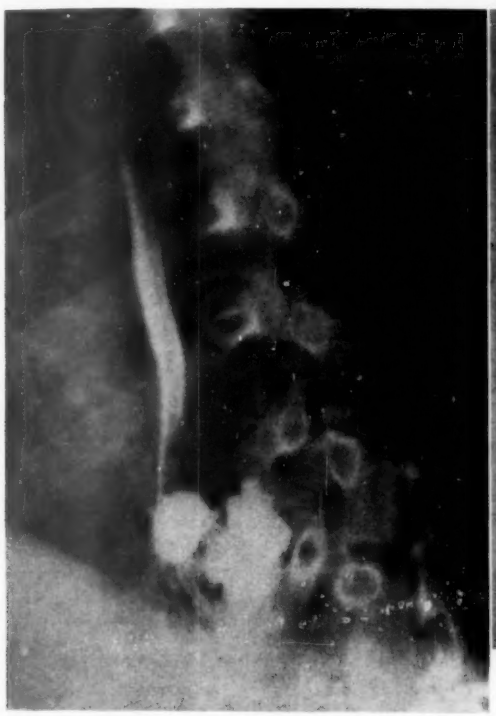

FIG. 1

FIG. 2

FIG. 1.—(Case 1) Oblique view after swallow of lipiodol to show extravasation of opaque medium into mediastinum.

FIG. 2.—(Case 1) Lateral view after barium swallow on the tenth p.o. day. Note the narrowing without obstruction. The AP view could not be reproduced satisfactorily.

The left thoracic cavity was entered through the bed of the ninth rib. The pleura was seen to be inflamed and the pleural cavity contained a quantity of dirty, dark gray-yellow material which had the typical appearance of gastric juice containing blood. As the lung collapsed, the lower lobe was found to be fixed to the mediastinum by fresh fibrinous adhesions. As this membrane was peeled off it was seen to be superficially necrotic in an area about 3 to 4 cm. in diameter. The lower mediastinum and the tip of the pulmonary ligament were necrotic and perforated. Dirty fluid exuded through the openings.

A cavity in the mediastinum about 5 by 3 by 2 cm. was entered through the necrotic mediastinal pleura. A brief attempt was made to visualize the esophagus in this area and then the diaphragm was opened and the fundus of the stomach and the abdominal esophagus were picked up and delivered into the chest. There was no evidence of perforation into the peritoneal cavity, but as the esophagus was freed in the esophageal hiatus, the necrotic reaction was seen to extend to the peritoneal side of the diaphragm. At a point approximately 1 cm. above the diaphragm, the lower end of a tear in the esophagus was seen. The longitudinal tear on the left posterolateral surface of the esophagus was over 4 cm. in length. The stomach tube lay against the opposite wall. Although a resection had been planned, a local repair appeared feasible at this time, so a three layer closure was performed. The first layer consisted of a running suture of 00 chromic intestinal catgut in the mucosa alone, the second of the same type suture through all layers and the third an inverting layer of Halsted silk mattress sutures in the muscularis. The mediastinum, especially in the necrotic area, was carefully irrigated and the organs were returned to their normal positions except for a long, thin tongue of omentum which was fixed upon the suture line. The diaphragm was then closed. The mediastinum was left open up to the root of the lung and the superior mediastinum was also incised, albeit with some difficulty because of the low incision. Chest closure was with three suction catheters, one posteriorly lying on the diaphragm with its tip very close to the mediastinum, one anterolaterally just lateral to the pericardium, and one anteriorly in the third interspace. One hundred thousand units of penicillin were sprayed over the mediastinal area.

FIG. 3.—(Case 1) AP view after barium swallow four months after operation. Outlined in dotted lines because of poor contrast. No narrowing or obstruction present.

The patient's immediate postoperative course was satisfactory, with relief of his pain, but with elevation of pulse, temperature and respirations. However, on the third postoperative day he rapidly developed a severe delirium reminiscent of delirium tremens and his course for the following few days was stormy. Delirium was controlled by paraldehyde and supportive measures including large doses of vitamins.

On the sixth postoperative day a friction rub was noted over the right lower chest, with effusion developing subsequently as shown by physical examination and roentgen ray. On the seventh postoperative day he showed evidences of thrombophlebitis of both lower extremities, but there were no further complications. The anterior drainage tube was removed on the seventh postoperative day, the antero-lateral tube on the twelfth postoperative day and the posterior tube on the sixteenth postoperative day. He was started on fluids by mouth as soon as his serious delirium permitted, on the seventh postoperative day. Roentgenogram of the esophagus on the tenth postoperative day showed narrowing of the esophagus on the lateral projection (Fig. 2) and minimal narrowing on the AP

projection. Repeat barium swallow on the twenty-second postoperative day revealed only minimal narrowing. A right thoracentesis was done on the twenty-third postoperative day and 50 cc. of fluid obtained, culture of which was negative. A gastric analysis on the twenty-sixth postoperative day revealed a fasting free acid of 20 units. He was discharged well on the twenty-seventh postoperative day, taking a full gastric diet without difficulty.

Additional note, May 8, 1949. Case 1 has been followed until this date and the patient has been eating a regular diet without any difficulty. Roentgenograms of the esophagus on Dec. 15, 1948, revealed no narrowing (Fig. 3).

Comment. This case showed the typical symptoms and signs of esophageal rupture. Despite this, the impressions of the first observers were of an intra-abdominal lesion rather than the correct diagnosis. When suspected, the diagnosis was quickly confirmed.

Case 2. J. R., N. H. H. No. 74073. This 75-year-old white male was admitted to N. H. H. Emergency Room at 7.45 P.M. on January 27, 1947, complaining of severe pain in the left side and the epigastrium.

The onset had been sudden at 10:35 A.M., approximately ten hours before admission, when he became nauseated and vomited while walking up stairs. Following this, there was no further vomiting but the severe pain persisted, despite small amounts of water and soda taken by mouth.

On admission he was evidently desperately ill, with pulse 100, blood pressure 100/70, respirations 30 and temperature 101.8°. There was splinting of the left chest with signs of fluid up to the level of the seventh dorsal spine. The abdomen showed slight distention with moderate tenderness in the epigastrium and l.u.q. There was evident cyanosis, and the extremities were cold.

The past history revealed previous admissions over a period of years to clinic and hospital for lues, nerve deafness, arterio-sclerotic heart disease and a ruptured appendix six months before this admission.

The WBC was 4,700, with 76 per cent polys. Urine examination revealed one plus albumin and two plus sugar without acetone.

The clinical diagnosis entertained by the medical staff in order given were (1) acute pancreatitis, (2) coronary occlusion, (3) incarcerated diaphragmatic hernia, (4) perforated stomach or duodenum, (5) subdiaphragmatic abscess and (6) hydronephrosis with pyelonephritis.

Roentgen ray showed a pleural effusion with pneumonitis on the left, dilatation of the large bowel with the question of a subdiaphragmatic mass on the left. He was treated with infusions and penicillin. His blood pressure fell rapidly and he died in collapse at 8:00 A.M., about 21½ hours after onset of his present illness. Just before death, a thoracentesis obtained foul brown fluid. Culture revealed mixed organisms.

At postmortem 1800 cc. of foul chocolate colored fluid were found in the left pleural cavity with complete collapse of the lung. The lower mediastinum was distended slightly to a point above the aortic arch with the same type of fluid. There was an opening 4 mm. in diameter from the mediastinum to the pleural cavity. Pressure on the stomach forced more fluid through this opening. There was a small pericardial effusion (30 cc.). On exposure of the lower esophagus, a 3 cm. longitudinal tear was seen on the anterior surface, with its lower edge at the esophageal hiatus. The edges were ragged and stained dirty brown. The edges of the mucosal tear, which was 6 cm. long, were sharp as if it were split by a scissors. The wall of the stomach and esophagus in this region were soft and unchanged except for slight edema. Microscopic examination showed plasma cells tightly packed in the mucosa, with some fibrosis of the deeper layers of the mucosa and submucosa.

Comment. This case history again is typical, and the course much more typical of rupture of the esophagus than that in Case 1. The diagnoses considered are those which have been made most frequently in previously reported cases. No mention was made of interstitial emphysema of the neck, but it may have been missed as by the first three observers of our Case 1. The roentgenogram showed a large bubble of air in the lower mediastinum which should have aroused suspicion of the esophageal rupture. The diagnosis could have been confirmed by the aspiration of a large quantity of foul fluid of the usual color from the pleura.

DISCUSSION

As shown by these two cases and outlined by previous authors, proper treatment of this condition depends on early diagnosis, for in most instances the course is rapidly down-hill with early development of shock, collapse and death. In many cases, death occurs within 24 hours and in the majority within 48 hours. Only 15 per cent survived more than 48 hours. This very rapid course may possibly be altered by modern chemotherapy and supportive measures, although this was not so in our Case 2 or in the more recent cases outlined above.

If rupture of the esophagus is kept in mind, the diagnosis should be entertained because of the distinctive symptomatology and then confirmed by the characteristic physical and roentgen ray findings. The patient is usually a male (five to one) who may or may not complain of previous epigastric or substernal discomfort. After a bout of drinking or other overindulgence, he suffers an attack of violent vomiting almost always with blood present, followed by severe high epigastric or substernal pain. Occasionally the pain first occurs in the back or is referred there early in the course. Referral of pain to the costal margin or to the left shoulder and pleuritic pain are frequent. A characteristic of the pain is its constancy. With or without signs of pleural involvement, limitation of respiration is usually a leading complaint.

The most valuable clinical sign for diagnostic purposes and the one most commonly present is cervical interstitial emphysema in the presence of low substernal or epigastric pain. In many cases there will be signs of pneumothorax, hydrothorax or both. The standard roentgenogram of the chest may show mediastinal gas shadows, sometimes with fluid levels. A definite diagnosis may be made by the demonstration that a swallow of lipiodol extravasates into the mediastinum or pleural cavity.

The erroneous diagnoses most frequently made in these cases include coronary occlusion, pulmonary embolus, dissecting aneurysm, perforated ulcer of the stomach or duodenum, acute pancreatitis and renal colic. As indicated in the case reports, perforated ulcer and renal colic were first considered in Case 1 and a melange of diagnoses were considered in Case 2. The diagnosis of an intraperitoneal surgical accident has been so strongly suspected in these cases that laparotomy has been carried out all too frequently.[1, 2A, 8, 14, 15, 17, 18, 22, 23]

Once the diagnosis of spontaneous rupture of the esophagus has been made, the treatment is surgical. Despite the shock-like picture, this must be performed early, combined with supportive measures. The experience with good, conservative treatment has been universally poor with a reported mortality of 100 per cent. In cases of perforation the need for surgery is not so urgent, as their course is less precipitously downhill. Even these cases, when treated conservatively, have a very stormy course, and their course undoubtedly would be shortened and the mortality decreased by early definitive surgery.

SUMMARY

A brief review of the previous experience with spontaneous rupture of the esophagus, its symptomatology and differential diagnosis have been given. Two cases of spontaneous rupture, one of which recovered as a result of early diagnosis and surgical treatment, have been reported.

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GASTROPERICARDIAL FISTULA FOLLOWING TRANSTHORACIC ESOPHAGECTOMY*

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The transthoracic approach to cancer of the esophagus and cardia is now well established. In the interest of collecting all possible data relative to this operation we present the first reported case of gastropericardial fistula occurring as the remote terminal complication in a case of transthoracic esophagectomy with esophagogastrostomy.

Case Report: In March, 1946, a 54-year-old white man was admitted to Cleveland City Hospital complaining of progressive dysphagia of 5 months' duration. Physical examination, blood count and blood chemistry showed no abnormalities. Radiograph of the chest was normal. Fluoroscopic and film studies of the esophagus and upper gastrointestinal tract showed an irregular constricting filling defect of the lower third of the esophagus with dilatation of the esophagus above the site of stricture. Esophagoscopy revealed an area of constriction but no definite tumor. Biopsy of the esophageal wall about the site of the stricture was reported as adenocarcinoma. On March 18, 1946, a transthoracic resection of the lower third of the esophagus and upper stomach was carried out with esophagogastrostomy. At operation there were no palpable lymph nodes in the mediastinum or hilum of the left lung and the procedure was carried out without incident. The pathologic diagnosis was partially differentiated adenocarcinoma of gastroesophageal junction consistent with carcinoma arising from gastric mucosa. The postoperative course was uneventful and the patient was discharged on the seventeenth postoperative day.

On October 14, 1946, he returned to the outpatient department complaining of substernal pain and dysphagia relieved by alkali. Esophagoscopy revealed an easily dilatable soft stricture 30 cm. from the incisor teeth (the stomal level) with an area of ulceration on the posterior wall of the stomach just beyond the stoma. Several biopsy specimens were taken about the stoma both proximally and distally. These sections were reported as showing papillomatous overgrowth of the squamous epithelium of the esophagus with adjacent ulcer formation; a silk suture was found in the sectioned material. Fluoroscopy and barium studies showed a patent gastroesophageal anastomosis which permitted barium to rush through easily. There was some evidence of gastric retention but no indication of recurrent tumor. The stoma was progressively and repeatedly dilated to No. 34. The patient was treated with antispasmodics and a bland diet regimen for the marginal ulcer, with fairly good clinical response.

Esophagoscopy in June, 1947, revealed a tumorous stricture of the anastomosis; biopsy of this area was reported as adenocarcinoma. Roentgen study (Fig. 1) at this time showed a constant fixed constriction of the distal esophagus with irregular filling defects in its borders. Radiograph of the chest showed a left pleural effusion and haziness of the left cardiac border with a double contour suggesting pericardial effusion. These findings probably represented the early manifestation of pericardial invasion by the recurrent tumor.

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The patient's final admission was in September, 1947, for increasing dysphagia, dyspnea, and persistent, boring left-sided chest pain. Examination now revealed a pale debilitated man with left pleural effusion, a liver that was palpably enlarged 6 cm. below the costal margin, and dilated superficial abdominal veins. Thoracentesis yielded 450 cc. of serosanguineous fluid which contained no tumor cells on microscopic cell block. On September 27, 1947, a Witzel gastrostomy was performed as a palliative feeding procedure. The postoperative course was characterized by fever, leukocytosis and progressively increasing dyspnea. Examination now revealed peculiar splashing and clicking

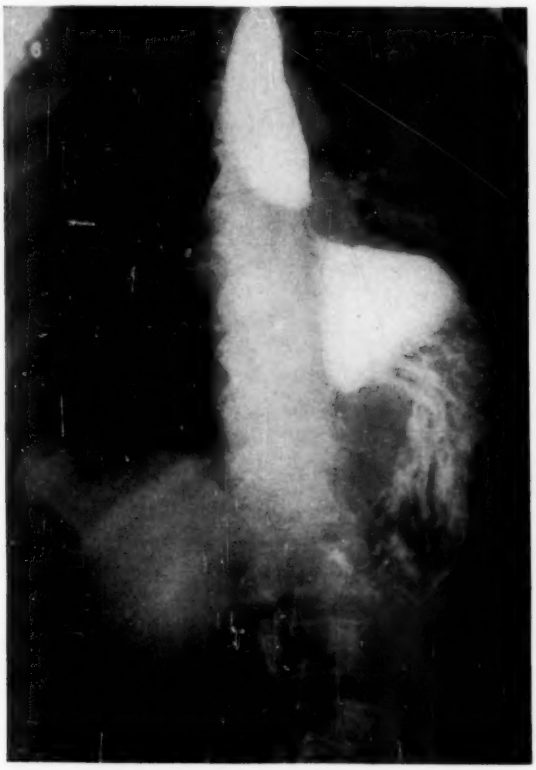

FIG. 1.—Examination in July, 1947, demonstrates an irregular, constant rigid, constriction of the distal 2 to 3 cm. of the esophagus with irregular defects in the mucosa at the esophagogastric junction, indicating recurrence of the carcinoma.

sounds in the heart cycle associated with distention of the neck veins and a venous pressure of 28 cm. of water. The electrocardiogram was typical of pericarditis. Chest radiographs (Figs. 2 and 3) showed a hydropneumopericardium. Aspiration of the pericardium was easily performed and the fluid and air were obtained very freely. The fluid was deep yellow with a specific gravity of 1.017, pH of 6.0 and showed yeast cells on smear. Pericardial aspiration offered the patient transitory relief of dyspnea but a film taken immediately following aspiration showed no change in the cardiac silhouette. Methylene blue swallowed by the patient could be aspirated from the pericardium. Repeated pericardial paracentesis and oxygen failed to relieve the cardiac tamponade and pericardiostomy was done on October 8, 1947, for decompression. The patient expired 36 hours after the procedure.

Autopsy. The most striking findings were in the chest. Both pleural spaces were partially obliterated by fibrous adhesions and there were 350 cc. of clear yellow fluid in the left pleural space and 200 cc. in the right. The left lung was firmly adherent to the pericardium, lateral mediastinum and posterior chest wall. The pleural surfaces of the left lung were markedly thickened. Sections showed the pleural thickening to be made up of partially differentiated adenocarcinoma. There was atelectasis of both lower lobes of the lungs. The walls of the pericardial sac measured up to 0.4 cm. in thickness and its inner surface was shaggy and dull gray. Histologic examination showed acute and chronic pericarditis with fibrin deposition. The pericardiostomy was represented by a defect in the anterior pericardial wall which measured 6 by 4 cm. and was continuous with the subcutaneous tissue of the right chest. In the posterior wall of the pericardium there was a large defect measuring up to 5 cm. in diameter through which the mucosal surface of the posterior wall of the stomach was seen (Figs. 4 and 5). The edges of this defect were composed of firm grayish white tissue and measured up to 0.8 cm. in thickness. Sections showed tumor tissue similar to that found at operation. This invaded all layers of the stomach wall and could be seen extending down into the pericardial wall. The inner lining of the pericardium blended with the submucosal of the underlying anterior stomach wall. The heart was enlarged in all diameters and weighed 525 Gm. Its epicardial surface was shaggy and gray and there was a recent laceration of the subepicardial fat which had been caused by the pericardial aspiration. There was no free fluid in the pericardial cavity. The site of the previous gastro-esophageal anastomosis was posterior to the pericardium. The distal 2 cm. of the esophagus was thickened and the walls were firm and grayish white. The lumen at this point was narrowed and measured 0.8 cm. in

FIG. 2

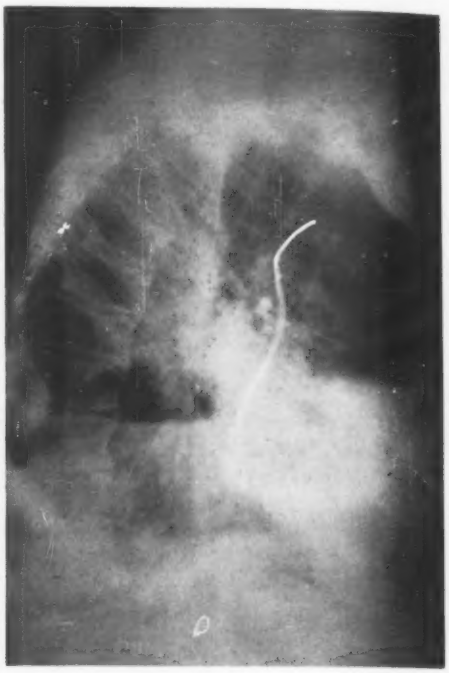

FIG. 3

FIGS. 2 and 3.—Radiographs of the chest show marked enlargement of the cardiac silhouette with thickening of the parietal pericardium most marked on the right. In the pericardial sac there is air and fluid and two large fluid levels indicating hydropneumopericardium. The left costophrenic sinus is obscured and there is a left pleural effusion.

diameter. Sections demonstrated the presence of tumor in the thickened portions of the esophagus. This was similar to that removed at the time of operation. The anterior surface of the esophagus and stomach were attached to the posterior pericardium and left lateral mediastinum by fibrous adhesions. There was a large deep ulcer in the mucosal

FIG. 4

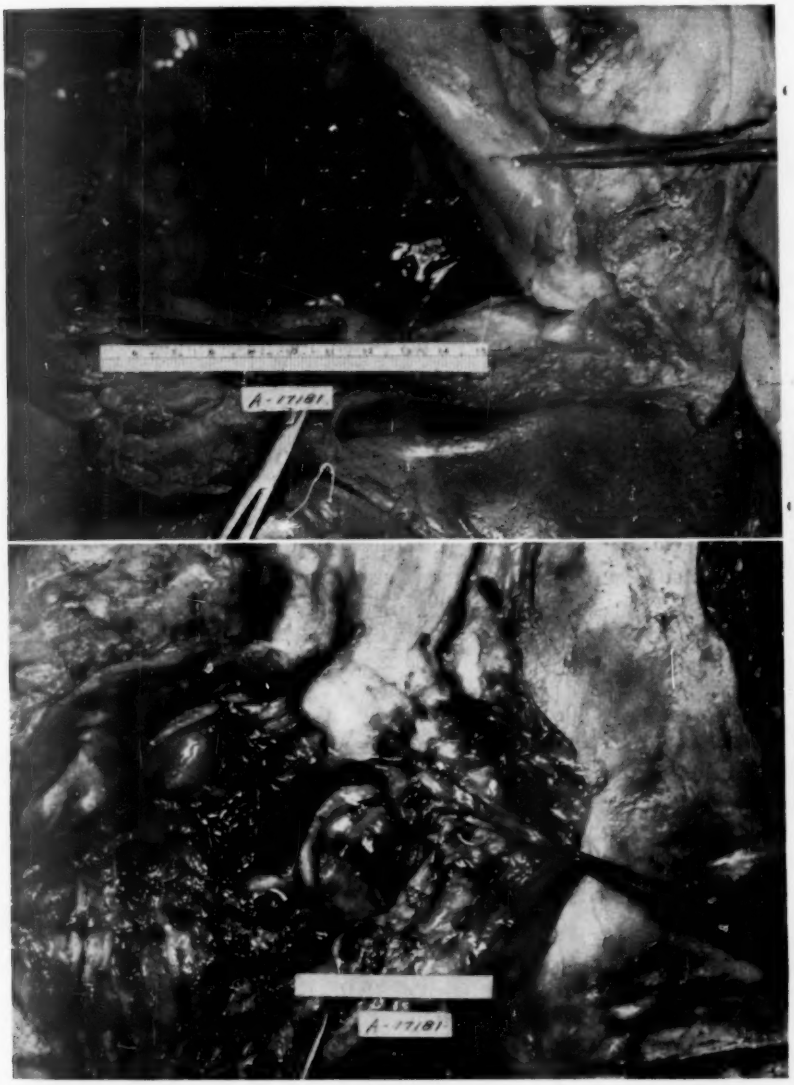

FIG. 5

FIG. 4.—Photograph taken at autopsy, with the apex of the heart retracted superiorly, demonstrates the greatly thickened pericardium and the 5 x 5 cm. gastro-pericardial fistula on the left posterolateral wall of the pericardial sac. The gastric mucosal folds are clearly seen through the fistulous opening.

FIG. 5.—Specimen removed at autopsy demonstrating carcinomatous thickening of the wall of the distal esophagus. The marginal anastomotic ulcer is well shown and just distal to this the gastric aspect of the fistula appears.

surface of the anterior wall of the stomach immediately distal to the site of the anastomosis. This measured 5 cm. in diameter and 0.6 cm. deep, and its edges were firm. Microscopically the base and edges of this ulcer showed tumor tissue. The large defect described above which opened into the pericardial sac was directly below this ulcer and was separated from it by a band of apparently normal mucosa 1 cm. in width.

In addition to the above finding there were small plaques of metastatic adenocarcinoma beneath the serosa of the right diaphragm, gallbladder, ileum, colon and cul de sac.

Anatomical diagnosis. Recurrent partially differentiated adenocarcinoma of esophagogastric junction with metastases to left lung, left pleura, mesentery, peritoneum, and mesenteric lymph nodes; gastro-esophageal anastomosis with marginal ulceration and gastro-pericardial fistula; acute fibrinous and chronic pericarditis; cardiac hypertrophy and dilatation; compression atelectasis of lungs; arterial and arteriolar nephrosclerosis.

Discussion. Gastro-pericardial fistula is rare. Gottesman and Benedick[2] in 1926 reported a gastro-pericardial fistula due to carcinoma of the cardia treated by radium implants, with subsequent necrosis and fistula formation. Abbot[1] in 1945 reported two cases of pericardial esophageal fistula, one congenital and the other occurring between the pericardium and a large epiphrenic esophageal diverticulum approximately six months following transthoracic diverticulogastrostomy. Other pericardial enteric communications have been reported: perforation of the esophagus into the pericardium by a foreign body and perforation of the esophagus into the pericardium by a tuberculous abscess.[3]

It is probable that the sequence of events leading to fistula formation in this case was postoperative adhesions between the stomach and the pericardial sac followed by invasion of the walls of both organs by residual carcinoma. This carcinoma tissue subsequently became necrotic and sloughed, leaving a direct gastro-pericardial communication.

Indirect evidence that the fistula was due to carcinoma in the stomach and not a pericardial metastasis is that Scott and Garvin[5] in a series of 11,100 autopsies found metastases to the heart and pericardium in only three cases of 262 tumors of the esophagus and stomach.[4]

The striking "splash murmur" and the characteristic roentgenographic appearance make the diagnosis of hydropneumopericardium relatively easy. The differential diagnosis of air and fluid in the pericardial sac must include bronchopulmonary-pericardial fistula and suppurative pericarditis associated with gas-producing organisms. In this case pericardial aspiration of swallowed methylene blue definitely established the enteric origin of the fistula.

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DIAPHRAGMATIC HERNIA WITH COMPLETE EVISCERATION OF THE LIVER*

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Diaphragmatic hernia has been quite thoroughly discussed in the surgical literature. Congenital herniations are usually diagnosed in childhood, whereas the acquired and traumatic types are most frequently seen in the adult. The case herein reported is unusual in that it represents a pleuroperitoneal hiatus in the right diaphragm of an adult with complete evisceration of the liver and gallbladder. It is of further surgical interest in that it was not diagnosed until serious symptoms developed following a right pyelolithotomy.

The development of the diaphragm is a complex embryologic process, a discussion of which is not pertinent to this paper.[1] It is sufficient to recall that the complex developmental evolution makes for many different types of hernia. Classification of diaphragmatic hernia on an embryologic basis is not always possible. Clinically the most simple and useful classification is that of Hedblom.[5] He divides all diaphragmatic herniae into three major groups: Congenital, acquired and traumatic. Further classification into sub-groups is possible but the three basic types satisfy most statistical requirements. Diaphragmatic defects when associated with evisceration of portions of the gastro-intestinal tract produce serious physiologic disturbances. It is significant that our case was asymptomatic until herniation of the colon was added to the evisceration of the liver. Congenital defects of the right diaphragm are much more rarely diagnosed than similar defects on the left. A search of the literature fails to reveal a single case described as total evisceration of the liver. Several cases of partial herniations of the liver through diaphragmatic defects are recorded but they are usually described as being lobular rather than total.[2-7] The case described below stimulates speculation as to whether it is possible for the liver to develop above rather than below the diaphragm.

Case Report (R. A.) A 54-year-old farmer was admitted to the Veterans Hospital, Lincoln, Nebraska, complaining of urgency and frequency of urination, terminal dysuria, dribbling and nocturia. The history revealed that 6½ years previously he had been injured in an automobile accident in which he suffered multiple fractures of the ribs, a fractured left patella and a fractured pelvis. Following the accident he was semi-comatose for two weeks and since that time had a speech defect and residuals of a right hemiplegia. An open reduction of the left patella was carried out and a suprapubic cystostomy was performed. He used an indwelling, suprapubic catheter for approximately

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two years after the accident. Following removal of the catheter the suprapubic sinus was closed surgically.

Physical examination on admission revealed a small, undernourished, white male who appeared chronically ill. He had a speech defect and showed evidence of mental impairment. He walked slowly with a shuffling gait. The chest was thin, symmetrical, with flaring of the costal margins and considerable muscular atrophy. The lungs were resonant and no adventitious sounds could be heard on auscultation. The heart was not enlarged to percussion. The sounds were normal and of good quality; there were no thrills or murmurs. The pulse was 90, regular, and of normal quality and rhythm. The blood pressure was 100/70. A right inguinal hernia was present but was not disabling. A moderate degree of prostatic hypertrophy was noted. The admission blood count was within normal

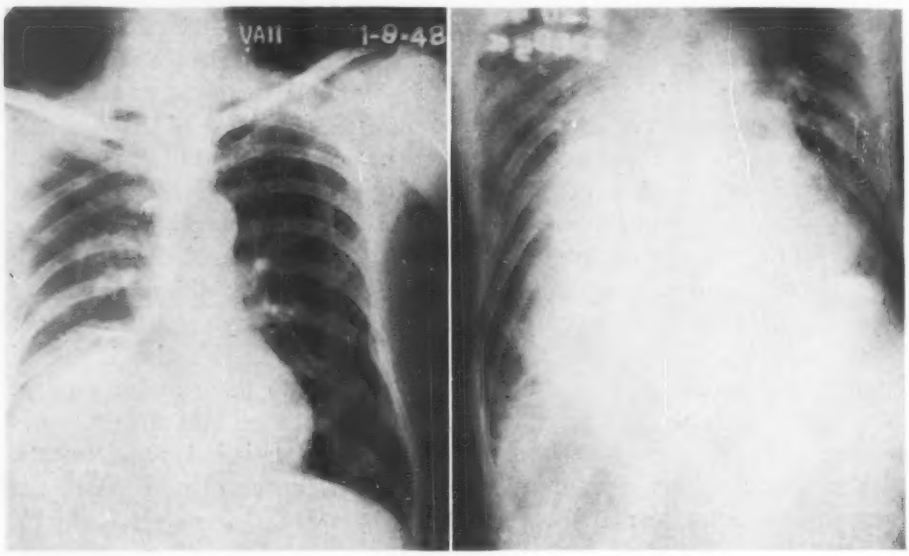

FIG. 1 FIG. 2

FIG. 1.—Preoperative roentgenogram. Routine chest plate. Interpreted as elevated right diaphragm with basal pleuritis.

FIG. 2.—Postoperative pyelolithotomy roentgenogram. Chest plate demonstrating large bowel shadow in thorax and absence of liver shadow below costophrenic angle.

limits. The urine was very cloudy, the reaction was acid, the specific gravity 1.012 and albumin 2 plus. Microscopic examination disclosed many white blood cells and culture revealed a mixed flora of colon bacilli and staphylococci. Wassermann and Kahn tests were negative.

A roentgenogram of the chest showed the trachea to be in the midline with no enlargement or displacement of the cardiac shadow. The aorta was somewhat tortuous. The right diaphragm was reported to be elevated and a pleural reaction appeared to be present just above it. There was an increase in the bronchial markings throughout both lung fields. There were healed fractures of the first 6 ribs on the right and what appeared to be a congenital defect in the first rib anteriorly on the left (Fig. 1). A roentgenogram of the abdomen revealed a huge amorphous calcium deposit in the region of the right kidney. Intravenous urography disclosed bilateral hydroureter and hydronephrosis, with a large calculus in the right ureter and renal pelvis.

On cystoscopic examination a small bladder with a severely trabeculated wall and a chronic cystitis was found. The ureteral orifices were abnormally located on the posterolateral wall of the bladder and each ejaculated a cloudy urine. The abnormal location of the ureteral orifices was thought to be due to the fact that the bladder was distorted by the previous longstanding suprapubic cystostomy. A diagnosis was made of calculus in the right renal pelvis; renal tuberculosis to be considered.

A right renal exploratory operation (by A. D. M.) revealed an enlarged kidney with an extremely dilated pelvis and ureter containing a huge elliptical calculus. The calculus was removed through an incision in the ureter and pelvis. The stone was yellow-grey in color and friable with a soft, caseous center. Cultures taken from the urine in the pelvis

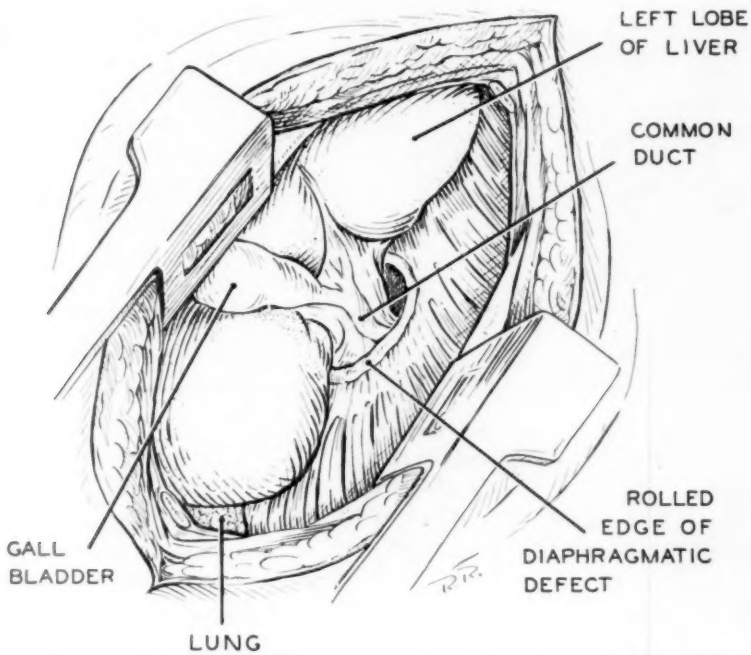

FIG. 3.—Partially diagrammatic drawing illustrating relationship of liver and gallbladder to the diaphragm. The herniated colon is not shown but entered the chest through the defect anterior to the porta hepatis.

revealed a mixed flora of colon bacilli, staphylococci and streptococci. Smears and guinea pig inoculation showed no evidence of tubercle bacilli. Renal function was good following the operation.

In the evening of the second postoperative day the patient developed a cough and became slightly dyspneic. In the morning of the third day abdominal distention, due to a combination of postoperative urinary retention and ileus, appeared. Despite antibiotics, prostigmine, nasogastric suction and retention urethral catheter his dyspnea and cyanosis increased. Physical examination of the chest at this time revealed a hyperresonance of the right hemithorax. Liver dullness was completely obliterated. There were no breath sounds audible in the right chest except immediately lateral to the sternum. The left lung field was filled with many coarse, moist, breath sounds. A diagnosis of postoperative atelectasis on the right was made. The patient was placed in an oxygen tent, encouraged to cough, and intermittent carbon-dioxide inhalations were prescribed. Roentgenograms

of the chest and abdomen discovered a large, gas-filled colon, extending into the right thoracic cavity producing an atelectasis of the right lung (Fig. 2).

Surgical consultation was requested and a diagnosis of right diaphragmatic hernia was made. Because of the respiratory involvement a thoracotomy was recommended. Therefore, in the evening of the third postoperative day the patient was subjected to a thoracotomy under intratracheal anesthesia (by W. P. K.). At operation the entire liver, the major portion of the transverse colon and the hepatic flexure of the colon were discovered in the right pleural space. There was a central defect in the diaphragm through which the organs had entered the pleural cavity. The defect was approximately 10 cm. in diameter, perfectly circular and with a thick, rolled edge. The liver was rotated upward and back and was attached at its apex to the posterior margin of the defect in the diaphragm by means of the central tendon. The gallbladder was present, lying above the liver (Fig. 3). It was impossible to return the liver into the abdomen through the existing defect in the diaphragm since the opening was much too small. An incision was made, therefore, extending the defect antero-laterally. The transverse colon was then reduced with ease. The liver was replaced by first inserting the left lobe through the defect in the diaphragm and then gradually manipulating the right lobe of the liver beneath it. Considerable difficulty attended this procedure due to the distended colon which quite completely filled the peritoneal cavity. The defect was closed under considerable tension with interrupted, heavy, nylon sutures. Good and adequate inflation of the lung was obtained and the thoracotomy wound was closed in a routine fashion without drainage.

FIG. 4.—Postoperative thoracotomy roentgenogram. The diaphragm is now seen to approximate its normal position. The liver shadow is now normally situated. The old, healed, rib fractures stand out clearly.

Postoperatively, the patient was maximally distended and energetic measures to combat this were immediately started. A Miller-Abbott tube was passed, prostigmine and pitressin were given and 8 cc. of 20 per cent hypertonic saline solution were given intravenously. Intravenous infusions and antibiotics were continued.

In the first day after the thoracotomy the abdominal distention had been largely relieved and breath sounds could be heard in both lung fields. After the abdominal distention subsided the Miller-Abbott tube was removed. The oxygen tent was discontinued on the fourth postoperative day at which time the respirations were normal and the color was good. He was ambulant on the fifth postoperative day and sutures were removed on the ninth. He improved rapidly but his hospital stay was prolonged because of a persistent urinary infection which was treated with appropriate antibiotics. A postoperative roentgenogram of the chest taken before discharge from the hospital revealed many healed fractures on the right and a resection of the right tenth rib. The diaphragm was elevated and there was some increase in the bronchial markings in the right base (Fig. 4).

He was discharged ambulant on the twenty-sixth day after thoracotomy. At that time he was asymptomatic and felt well. He was readmitted and observed five months after his discharge. During the latter admission the urine was found to be infected and he was treated with streptomycin and sulfathiazole. Fluoroscopy of the chest at this time revealed an active right diaphragm with some fixation laterally but no evidence of herniation. He was discharged after treatment for the urosepsis.

DISCUSSION

A study of this case develops several interesting questions as well as emphasizing certain findings. In the first place, it emphasizes the importance of studying roentgenograms not only in order to interpret obvious pathologic conditions but also to evaluate all unusual findings. After a review of the roentgenograms one must conclude that failure to note the absence of the liver shadow in the preoperative scout films was an embarrassing oversight. An important clinical observation is made in that the presence of a defect in the diaphragm with the liver above it is a completely asymptomatic condition. Symptoms relative to the diaphragmatic defect were not produced until postoperative ileus forced distended bowel into the thorax. This suggests that symptoms of diaphragmatic hernia are, in general, associated with disorders in function of the gastro-intestinal tract. Respiratory symptoms are secondary.

The importance of bedside roentgenography in the diagnosis of postoperative pulmonary complications should be stressed. Although an astute diagnostician can quite readily make a differential diagnosis of postoperative pulmonary complications from physical findings alone it imposes a serious burden on the junior staff members who so often see such conditions first. The help that a bedside chest plate offers should not be neglected in the evaluation of serious postoperative pulmonary complications. Without a postoperative chest film the case under discussion might well have been considered a case of massive pulmonary atelectasis.

It is interesting to speculate as to the etiology of the hernia in this case. Certain aspects strongly suggest a congenital origin of the diaphragmatic defect. However, the possibility of a traumatic origin cannot be excluded. Central defects of the diaphragm are rare whether congenital or traumatic in origin. A central defect on a traumatic basis is possibly somewhat more difficult to postulate. It would assume spontaneous healing of a torn diaphragm with the exception of a small opening for the porta hepatis. On the other hand, an embryologic explanation also meets with serious objections. A central defect implies failure of development or fusion of the pleuroperitoneal membrane. Studies of the embryologic development of the diaphragm seem to indicate that the liver and adrenal glands play an important role.[1] It scarcely seems possible for an essentially normal diaphragm to develop below the liver. Finally, we cannot ignore the history of trauma. The violence this patient suffered in the automobile accident was serious enough to be just sublethal. The residuals are still present in the form of cerebral damage, healed fractures of ribs and, indirectly, probably even the renal calculus. A traumatic origin of

the hernia must, therefore, receive first consideration despite difficulties in the interpretation of the findings.

SUMMARY

1. An unusual case of pleuroperitoneal hiatus of the right diaphragm is described. It is believed to be the first case reported of a supra-diaphragmatic liver in an adult.

2. The importance of a careful study of all roentgenograms is re-emphasized. If, as in this case, attention is directed exclusively at obvious pathologic lesions, associated conditions will often be overlooked. The judicious use of bedside roentgenography in the postoperative period is also stressed.

3. The etiology of the condition is discussed, although no satisfactory conclusions are drawn. The factors involved in considering this either as a congenital or traumatic form of diaphragmatic hernia are presented. The explanation in either case results in an incomplete description of the course of events.

4. The development of symptoms in the postoperative period due to a patent pleuroperitoneal hiatus is described. The operative treatment and successful outcome of the case are reviewed.

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HOURGLASS STOMACH CAUSED BY ANNULAR MUSCULAR HYPERTROPHY*

REPORT OF A CASE

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Hypertrophy of the pyloric muscle of the stomach is well known in infants, and a number of cases in adults have been reported. However, hypertrophy of the muscular layers of the stomach of the proximal portion of the antrum causing an annular constriction partially dividing the stomach into two compartments, and giving rise to an hourglass appearance on roentgenographic examination apparently has not been reported. The following is the story of such a case.

CASE REPORT

A 74-year-old white male was admitted to the hospital January 17, 1948, with the chief complaint of pain in the epigastrium of a month's duration. This pain occurred an hour or two after meals and was associated with the sensation that the stomach was overfilled and could not empty. There was some nausea with the pain, but no vomiting. The patient lost six pounds during this period. No jaundice, hematemesis, or diarrhea had been noted.

Six years previously there had been similar symptoms which subsided when the patient followed a bland diet.

Previous records showed that the Wassermann test had been positive in 1928. He had received anti-syphilitic therapy. Records since 1945 showed repeatedly negative serologic tests.

Significant points in the physical examination included some mental confusion, a shuffling gait, partial deafness, blood pressure 180/94, palpable liver edge, and some observers noted a non-tender mass in the epigastrium.

The following laboratory examinations were within normal limits: blood count, urinalysis, sedimentation rate, blood and spinal fluid Wassermann, colloidal gold curve of spinal fluid, and serum proteins. NPN was 48. Gastric analysis showed 60° of free acid and 76° total.

Roentgen-ray examination (Dr. T. Pfeffer) of the stomach after ingestion of barium showed a localized deformity in the nature of an annular constriction approximately 2.5 cm. in extent near the proximal portion of the pylorus. A freely movable translucent mass 2.5 by 3 cm. was present in the stomach proximal to the deformity (Figs. 1 and 2). This deformity was constantly present on repeated examinations.

In spite of the gastric acidity and normal sedimentation rate, a tentative diagnosis was made of carcinoma of the stomach. The movable mass seen in the stomach was thought to be a foreign body, probably, a trichobezoar, or possibly a pedunculated, polypoid tumor.

On February 10, 1948, the patient was operated upon. There were some old adhesions between the omentum, gallbladder, liver and duodenum, and a firm constriction of the stomach approximately 5 cm. proximal to the pyloric sphincter. This was about 3 cm.

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FIG. 2.—Roentgenogram of stomach after partial emptying showing the constantly present defect.

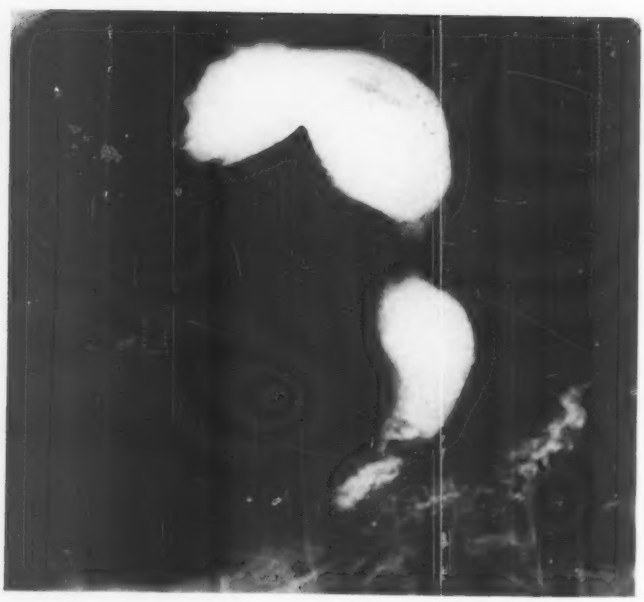

FIG. 1.—Roentgenogram of stomach showing the hourglass appearance and the area of translucency proximal to the deformity.

thick. The overlying serosa was normal. Posteriorly, this area was somewhat adherent to the peritoneum over the pancreas. There were no nodules found in the liver, adjacent ligaments or omentum, and the regional lymph nodes did not seem to be involved in tumor. There was no free fluid.

Because of the patient's age, and because there was some question as to the diagnosis, a partial rather than a total gastrectomy was decided upon. The distal two-thirds of the stomach was removed down to the pyloric ring. The duodenal stump was closed and an ante-colic, anti-peristaltic anastomosis was made between the cut end of the stomach and the side of the jejunum about 30 cm. from the ligament of Treitz.

Recovery was uneventful and the patient was discharged March 2, 1948. Since then he has remained free of pain, complaining occasionally of a poor appetite.

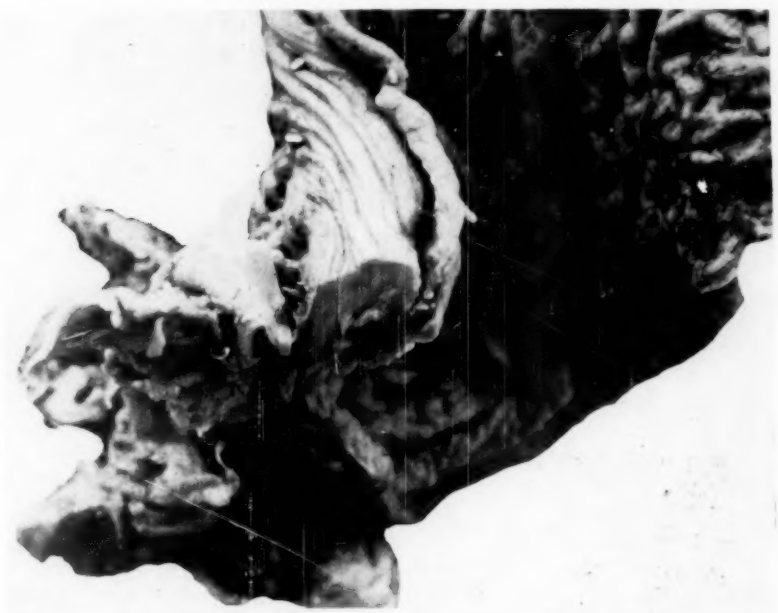

FIG. 3.—Gross specimen of stomach showing cross-section of thickened muscle.

Pathologic Report (Dr. Joseph Lubitz): "*Gross:* Upon examination of the specimen, the tumor was seen to be a firm constricting area of thickened stomach wall measuring 2 cm. in width, located 4 cm. from the pyloric end of the stomach. This thickened band cut with increased resistance, and it was uniformly shiny yellow-white in color. On cross-section of the stomach wall this mass was found to involve the muscularis and measured 7 mm. in thickness. At the point of constriction the lumen measured but 1 cm. Between the pyloric end of the specimen and the muscular band the stomach wall was of normal thickness in diameter. A peach pit lay in the proximal portion of the specimen. The mucosa appeared normal throughout (Fig. 3).

"*Microscopic:* The mucosa is intact. Under the mucosa there is hypertrophy with replacement by fibrous tissue of the submucosa. The thickening of the stomach wall is primarily due to hypertrophy of the musculature. With special connective tissue stains, it can be seen that the fibrous stroma accompanying the hypertrophied muscle is minimal. The serosal surface is only slightly thickened (Fig. 4).

"*Diagnosis:* Annular constriction due to muscular hypertrophy."

The peach pit accounted for the area of decreased density seen on the roentgen-ray film

DISCUSSION

Since Beardsley's report of a case[3] of congenital hypertrophic stenosis of the pylorus, the condition has come to be a well-known lesion in infants. More recently the existence of a similar lesion in the adult has been recognized

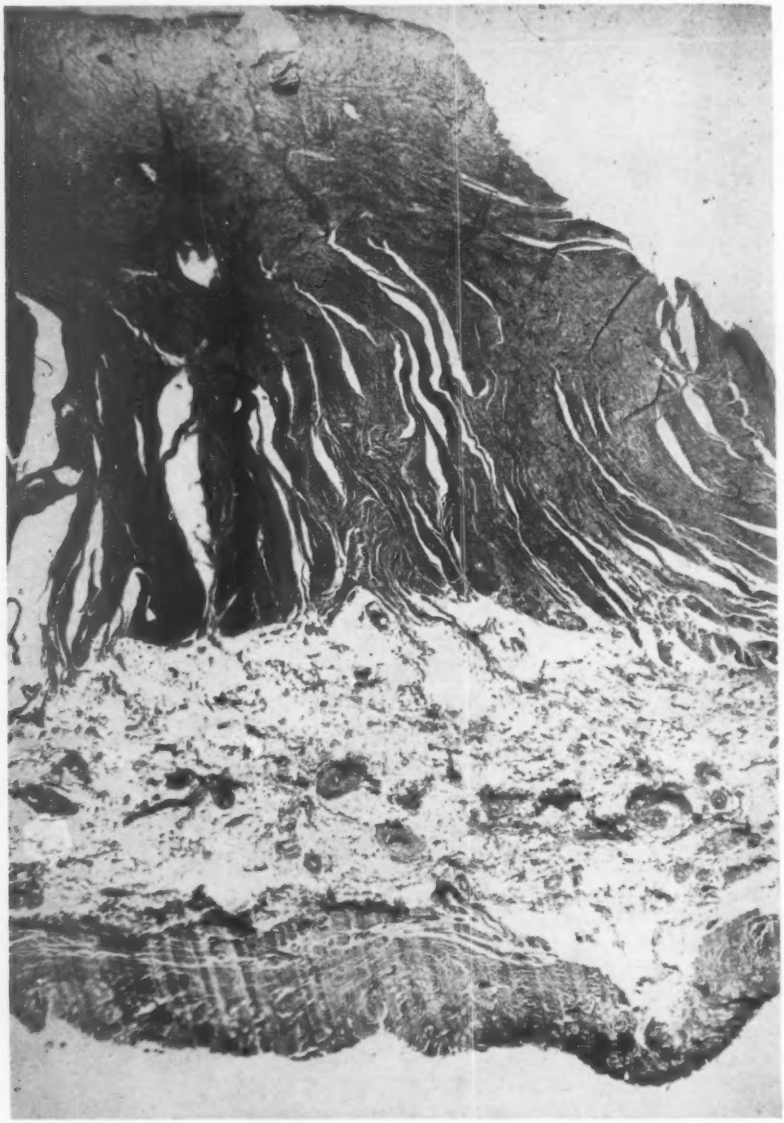

FIG. 4.—Low power photomicrograph showing thickened muscular layer of stomach wall.

and numerous cases have been reported, including a series of 81 cases seen in a four-year period by Kirklin and Harris.[7] Localized, annular, constricting hypertrophy of the stomach muscle elsewhere in the stomach does not seem to have been reported.

Normally the muscular layers of the pyloric antrum are slightly thicker than in the remainder of the stomach. The circular fibers are greatly increased to form a sphincter just proximal to the duodenum. In hypertrophy of the pylorus of adults the enlarged muscular mass consists of circular (and oblique) fibers of the antral musculature, separate from and proximal to the normal, circular pyloric sphincter.[1, 5, 10] The niche separating the sphincter from the hypertrophied muscle is one of the radiologic criteria for diagnosis of pyloric hypertrophy. Ordinarily this hypertrophy extends several centimeters proximally into the antrum, forming a funnel-shaped canal which is widest at its oral extremity.

Pyloric stenosis in the adult has been attributed to persistence of a congenital pyloric hypertrophy and also to the development later in life of hypertrophy of the pyloric muscle, the cause of which is not clear, but possibly may be a gastric ulcer which has healed.[4, 11, 12] The appearance under roentgen-ray has been described and the radiologic criteria for diagnosis have been well defined.[1, 2, 7, 9, 10]

In the above described lesions, however, the point of greatest constriction of the lumen of the stomach has been in the distal portion of the pylorus. In the case described here the constriction occurred in the more proximal portion of the antrum, causing an hourglass constriction of the stomach into two compartments.

Hourglass deformity of the stomach is usually secondary to an intrinsic ulcerative process, usually benign, but sometimes secondary to neoplasm or to syphilis.[4, 6, 8] In the present case the mucosa was intact. There was no scarring or other evidence of ulcer. The lesion was entirely in the muscular layer. The interpretation of the roentgen-ray films led to a diagnosis of carcinoma. The cause of the hypertrophy of the muscle remains undetermined.

It seems probable that the short duration of symptoms was due to the recent ingestion of a peach pit and the resultant intermittent obstruction of the constricted area.

SUMMARY

A case is described of annular constriction of the stomach caused by hypertrophy of the musculature proximal to the pyloric region giving rise to an hourglass stomach which resembled carcinoma upon roentgen-ray examination.

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COARCTATION OF THE AORTA AT THE LEVEL OF THE DIAPHRAGM*

CASE REPORT

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SINCE CRAFOORD'S REPORT in 1945[1] describing a successful surgical procedure for coarctation of the aorta, there has been increased interest in this congenital vascular anomaly. Gross,[2] Crafoord[3] and others[4, 5] have reported successful operations in an appreciable number of cases.

The infantile type of coarctation of the aorta is usually not compatible with life. Those patients who survive infancy and childhood have the adult form of coarctation, which is manifest by a stenotic segment, most often located between the left subclavian artery and the ductus arteriosus or ligamentum arteriosum. Variations in location occur a few millimeters in either direction.

This case report is that of a young woman who at operation was found to have a coarctation of the aorta just above the diaphgram (Fig. 1). Investigation of the literature revealed that Schleckat[6] in 1933 reported such a case in a 44-year-old man. His patient died with a diagnosis of aortic insufficiency. Autopsy revealed a coarctation of the aorta just above the diaphragm. The stenotic segment was narrow and its lumen admitted only a 3 mm. probe. The aorta above the stenosis was enlarged and below was of about normal size. The collateral arterial channels were dilated. Costa[7] in 1930 described a stenosis of the aorta between the first and second intercostal arteries. Hickl[8] in 1931 reported a constriction of the aorta located below the ductus arteriosus measuring 6 cm. in length. This was considered as probably inflammatory in origin. Our case is, apparently, the second one, in the low thoracic aorta, to be reported, and the first one for which an operation was performed.

CASE REPORT

The patient, 20 years old, was admitted to the John Gaston Hospital on February 18, 1948. Since July, 1947, she had been troubled with attacks of dyspnea, palpitation, and tachycardia. Exercise or excitement increased these symptoms; the attacks lasting only a few minutes. She had had severe headaches since the age of nine years. Episodes of pain in her arms and legs had occurred since November, 1947. She was handicapped to the extent that she could not do much housework. The past history was non-contributory.

Physical examination revealed a well developed young colored female. The arterial pulsations in her neck were increased bilaterally. The blood pressure in her left arm was consistently higher than that of the right arm, and varied between 180/140 and 200/140. The pressure in her right arm varied between 120/100 and 130/100. Blood pressure readings were never obtainable in her legs, nor were pulsations ever palpable. Her heart was questionably enlarged and a systolic murmur was heard posteriorly over

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the tip of the scapula. There were no palpable pulsations of the intercostal arteries. Her RBC was 4,600,000; hemoglobin 12½ Gm.; blood Kahn negative. Roentgenogram of her chest revealed a moderate enlargement of the heart, the contour indicating left ventricular enlargement. Minimal erosions were reported on the inferior surfaces of the fourth, fifth, sixth, and seventh ribs bilaterally. The aortic knob was present but not prominent. The lung fields were clear. A preoperative angiocardiogram was attempted, but was unsatis-

FIG. 1.—Drawing to demonstrate the low position of the coarctation.

factory. The clinical diagnosis was coarctation of the aorta, and on March 10, 1948, operation was performed.

Operation. Under cyclopropane endotracheal anesthesia, an approach was made through the left chest by dividing the intercostal muscles in the fourth interspace. Posterior segments of the third, fourth, fifth, and sixth ribs were removed. On freeing the parietal pleura, a dilated aorta was found, with no constriction. Pulsations of the aorta were quite forceful. The left subclavian artery was not enlarged. As far as the thoracic aorta could be visualized, no constriction was present. The intercostal arteries were not

dilated. The low thoracic aorta could not be visualized, but by palpating low in the chest, there was thought to be a constriction in the aorta just above the diaphragm. An actual constriction could not be felt, but the pressure in the low aorta at the level of the diaphragm seemed to be definitely less than that of the aorta above, and a point of merging from one pressure to the other could be localized to an area of about one finger's breadth in the aorta. Three diodrast angiograms were made on the operating table by injecting directly into the aorta; but the portable roentgen ray, due to its low power, failed to reveal any filling of the aorta. In view of the low level of the coarctation it was considered advisable to terminate the operation and approach the area later through a more suitable incision.

FIG. 2.—Cross-section of specimen showing marked thickening which is chiefly intimal. Separation of the intima and media can be seen.

Second Operation. On April 9, 1948, operation was performed at a lower level in the left chest. A postero-lateral incision was made parallel to the ninth rib with resection of posterior segments of the seventh, eighth, and ninth ribs. Exposure was difficult because at this level the aorta was lying directly over the vertebral column in the midline. A coarctation was found, approximately 5 cm. above the diaphragm. The diameter of the aorta above the site of coarctation was the same as that below; the aorta in this region, however, was somewhat smaller than the aorta higher in the chest. Very little blood was passing through the stenotic area, judging by the absence of pulsations in the aorta below. The intercostal arteries, above and below the stenotic area, were of normal size. There was concern over probable difficulty in approximating the aortic ends since the stenotic area was rather long and the aorta rigid. The Bradshaw clamp[9] was applied and the stenotic segment measuring 17 mm. in length was excised. The lumen of the specimen

at the maximum point of constriction was 4 mm. in diameter (Fig. 2). The ends of the aorta were under considerable tension and could not be approximated. The proximal Bradshaw clamp began slipping and it was necessary to apply the modified Moynihan clamp, recommended by Gross, to the proximal aorta. This clamp held very well but still the aortic ends could not be brought together. The aorta had no elasticity at all. Four or five sets of intercostal arteries were divided until 12 cm. of aorta was mobilized. This did not permit any further motion of the aortic ends. Since it was impossible to join the ends of the aorta an iliac vein graft[10] was considered as a bridge for the defect, but the patient had been under anesthesia for five hours and was developing pulmonary edema. The extra time which would be necessary for procuring such a graft was considered out of the question, and there was no assurance that such a graft would withstand the increased pressure of the aorta without rupture or subsequent aneurysm formation. No plastic prosthesis[11] was available. Under the circumstances, the only choice left was to close the ends of the aorta with sutures, hoping that the collateral circulation would be adaquate. The patient died approximately five hours after the operation. Permission for autopsy was refused.

DISCUSSION

The etiology of coarctation in the low thoracic aorta can not be explained on the basis of existing theories[12] of which we have any knowledge. The most widely accepted theory of skodiac,[13] dealing with the extension of an obliterative process from the ductus arteriosus into the aorta, would not be applicable in this case. The possibility of inflammatory origin of the stricture is not borne out by microscopic study of the specimen.

The unusual location of the coarctation in this patient was not suspected until failure to find a constriction in the upper thoracic aorta, at the time of the first operation, led to further exploration. The radiographic report of the presence of an aortic knob had been commented upon prior to operation, yet the arch was not prominent, and in a fair percentage of cases of high coarctation the arch can be seen on roentgen ray examination. It is doubtful, therefore, that visualization of the aortic arch should necessarily lead one to suspect a low coarctation.

Three attempted diodrast angiograms during the operation failed to outline the low aorta. This failure was due to the low power of the portable roentgen ray used. It might be pointed out that relatively small, 21-gauge, needles were inserted obliquely into the aorta for the injections, and following withdrawal of the needle each time, blood spurted from the aorta for a distance of six to ten inches, and could be controlled only by the use of gelfoam sponges, and even then with difficulty. In view of this experience I would question the safety of a blind insertion of an 18-gauge needle into the aorta, through the back, as recommended by some,[14] for the purpose of obtaining an angiogram in patients with increased aortic pressure.

There was consistently a distinct difference in the blood pressure of the two upper extremities, with the greater pressure in the left arm. The blood pressure in the left arm varied between 180/140 and 200/140, while that in the right arm was 120/100 to 130/100. Reifenstein[15] noted that, uncommonly, there might be a marked difference of circulation of the two upper extremities.

This usually consists of a decreased circulation in the left arm because of encroachment upon the orifice of the left subclavian artery by the coarctation, which results in partial occlusion of that vessel. King[16] in 1939 reviewed blood pressure readings in 170 reported cases of coarctation and added five more cases to the literature. There were only ten cases in which a significant disparity of pressure in the two arms was present, and of these ten patients nine had higher pressure in the right arm, possibly due to involvement of the isthmus of the aorta and the mouth of the left subclavian artery in the same fibrotic anomaly—an explanation offered by Parkes, Weber and Knop.[17] East[18] reported one case in which the blood pressure in the left arm was 195/145 and in the right arm was 135/100. No autopsy examination of the patient was made, however. In a second case, upon which clinical observations were not available, autopsy revealed stenosis of the isthmus of the aorta and an anomalous origin of the right subclavian artery which might have resulted in interference to the circulation of the right arm. Love and Holmes[19] in 1939 reported a case with a blood pressure in the left arm of 210/95 and in the right arm 150/90. At autopsy the right subclavian artery, at its origin from the innominate, was stenosed.

In our case the right chest was not explored and permission for autopsy was refused, so there was no opportunity to examine the right subclavian artery.

Another unusual feature of this case was the absence of dilatation of the intercostal arteries in the left chest. Since approaches were made in both the upper and lower chest on the left, a satisfactory view of most of the intercostal arteries was possible. The roentgen ray diagnosis of rib notching was obviously in error. Possibly, the internal mammary artery served as the major channel for collateral blood.

A distressing finding at operation was the lack of elasticity of the low thoracic aorta. This feature was noted before the coarctate segment was excised so that a minimum length of the strictured vessel was removed, the resected segment measuring 17 mm. in length. In both cut surfaces the intima and media separated and the aorta was pipelike in consistency. The aortic ends could not be approximated and extensive division of intercostal arteries did not give additional mobility. In the upper aorta, freeing of the arch and the left subclavian artery usually permits some straightening of the aortic arch with the result that additional length can be obtained for the proximal aortic segment. No such movement was possible in the low thoracic aorta of this patient.

Substitution of some material is obviously necessary in instances where a rigid aorta is present and the aortic ends cannot be approximated. The use of a vein graft as recommended by Blakemore was considered in this case but was not used for reasons mentioned earlier. Plastic prostheses have been used by Hufnagel in dog's aortas, but its value in human beings for permanent intubation is open to question. In past years many metals and plastics[20-22]

have been used as substitutes for defects in large arteries, with generally unsatisfactory results. Gross[23-25] recently, both experimentally and clinically, has used preserved arterial grafts with success. This method appears promising and would have been the technic of choice in the case reported here if such a graft had been available.

SUMMARY

A case is reported of coarctation of the low thoracic aorta just above the diaphragm. Apparently, this is the first such case for which surgery was attempted, and the second case in which coarctation has been found in that position.

The unusual features of the case and its surgical problems are discussed.

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(*Continued on page* 1118)

UNILATERAL MACROSTOMIA*

A CASE REPORT

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THIS CASE of macrostomia is reported because of its rarity, only five cases having been reported in Europe since 1881. No cases have been reported in America. The condition is generally held to be a fusion fault of the mandibular and maxillary processes, producing a cleft cheek in the same general manner as the fusion fault of the maxillary and naso-frontal processes produce a cleft lip. All the cases reported, including the present one, have been unilateral

FIG. 1.—Preoperative view showing deformity.

In 1881, Dr. J. H. Morgan[1] presented two cases of macrostomia that had been seen and operated upon. Both of these were closed in a straight line. The next case is reported by Clarke in 1900.[2] This case had an associated deformity of the hand. In discussion of this case, the group assumed that the child had its hand in its mouth in utero. In 1910, Sidoun[3] reports a case from Paris in which there was accompanying deformity of the ear on the same side. In 1936 Eitner[4] reports a case also complicated by gigantism of the ear with supernumary pre-auricular buds. In this latter case the mouth on

* Submitted for publication December, 1948.

the normal side measured 2.8 cm. from the midline and 4.6 cm. on the affected side.

CASE REPORT

(E. R.)—The patient was a 16-month-old female infant, the third child of healthy parents. The other children had no deformities and the parents could recall no other members of the family that had any deformities. The patient was a full term normal delivery. The deformity was noticed at birth and the mother stated that it seemed larger then, in relation to the size of the head, than at time of this examination.

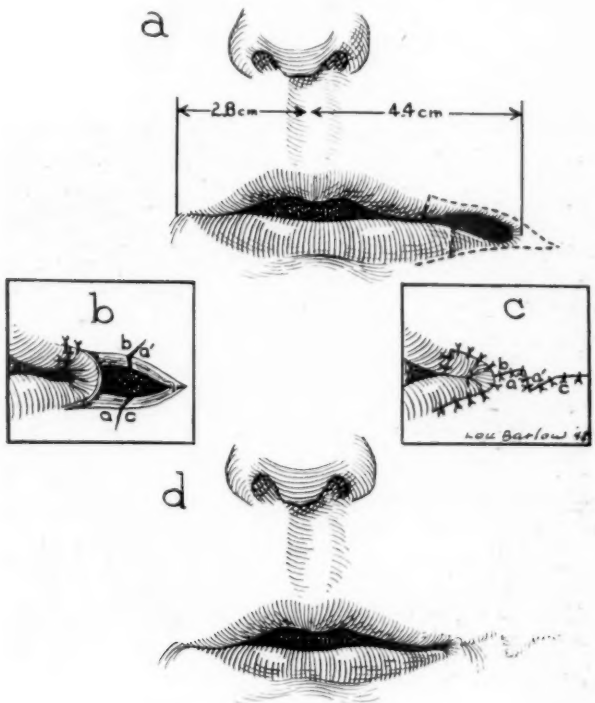

FIG. 2.—Operative Procedure:
(a) Proposed incisions.
(b) Vermillion flap rotated for commissure. Incisions for z-plasty.
(c) Closure of z-plasty.
(d) Result.

Physical examination revealed a well-nourished and, except for the mouth deformity, a well-developed child. There were no other deformities. The macrostomia was on the left side, the abnormal commissure being 1.6 cm. farther on the cheek than the normal commissure. The exact measurements from midline to commissure on the right were 2.8 cm. and on the left, 4.4 cm.

The patient was operated upon under general anesthesia using ether via nasal endo-tracheal intubation. Measurements equal to the normal side were marked on the vermillion border of the affected side. A small section of the vermillion of the upper lip medial to the marking of the new commissure was excised. A small flap of vermillion from the lower lip lateral to the marking was elevated and swung up and around into the

defect on the upper lip forming a new flexible commissure. The remainder of the vermillion of the macrostomia was excised. The orbicularis oris was identified and mobilized. The upper and lower portion were sewn together behind the commissure. Angular incisions were then made in the edges of the remaining cheek defect, producing two small pointed flaps which were transposed and a z-plasty was done. This was to avoid a linear scar pull on the corner of the mouth.

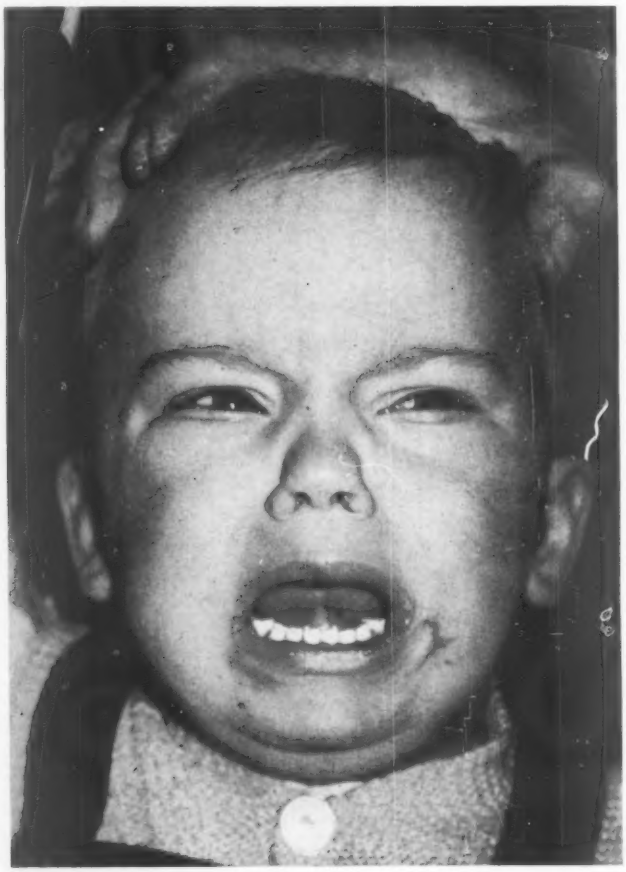

FIG. 3.—Postoperative view showing symmetric mouth.

The final result is good. The mouth is symmetric and water tight. Movement and expression is normal. The skin scars leave something to be desired and may have to be revised later.

SUMMARY

A case of macrostomia, a rare congenital defect, is presented together with the method of surgical treatment.

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BASAL CELL CARCINOMA OF THE ANUS*

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WE HAVE been able to find only eight reported cases of basal cell epithelioma of the anus (see Table I). Rosser,[1] in a review of the literature since 1915, referred to a basal cell carcinoma arising in a fistula. In 1933 Buie and Brust[2] reported 2939 malignant lesions of the anus and rectum encountered during a 13 year period at the Mayo Clinic; 51 of this group were primary

TABLE I.

Author	Age	Sex	Clinical Findings	Treatment	Outcome
Tucker and Hellwig 1938	43	M	Early, less than 2 cm. Origin in hair follicle	*Local excision radium	No recurrence at 3 years postop.
Guess 1935	52	M	Early, 2 cm.	*Local excision radon seeds	Died of coronary occlusion at 5 years postop.; no sign recurrence
Gabriel 1946	70	M	Early, 1-2 cm. Diagnosed by biopsy prior to surgery	Excised by cutting diathermy	No recurrence one year later
Buie and Brust 1933	53	F	Advanced, size of orange; also extensive mass in left groin	Radium advised; went home without treatment	Unknown
Buie and Brust 1933	53	F	Advanced, annular lesion	Colostomy and posterior resection; half vagina and local nodes removed	Recurrence 8 mo. Death 9 mo.
Lawrence 1941	73	M	Advanced, hard, annular fungating neoplasm (at operation found to invade prostate and membranous urethra)	Loop colostomy and posterior resection of anus and rectum	Died in 2 years
Lawrence 1941	73	M	Advanced, annular, fungating; completely involving anus and extending at least 2 cm. into adjacent perineum and peri-anal tissues	Colostomy and posterior resection of anus and rectum	Died several days postoperatively; no autopsy
Rosser 1931	No mention		No mention	No mention	No mention

* Local excision prior to establishing diagnosis by tissue study.

anal neoplasms, and of the 51, only two were basal cell cancers. In 1935 Guess[3] described one basal cell epithelioma; he made the observation that among 150,000 biopsies at the State Institute for Malignant Disease at Buffalo there were no others reported. Tucker and Hellwig[4] in 1938 reviewed 951 cases in which every specimen at anorectal operation was examined micro-

* Submitted for publication January, 1949.

scopically; only one basal cell cancer was found in this series. In that same year Gabriel[5] described his only case, and in 1941 Lawrence[6] reported two cases.

The early diagnosis of anal basal cell carcinoma presents considerable difficulty. Only one of the three early lesions reported (see Table I) was diagnosed by biopsy preoperatively. A basal cell tumor of the anus does not readily lend itself to biopsy since the growth tends to grow away from rather than toward the surface of the anal mucosa. When this tumor is observed in its early stages it may easily be mistaken for any one of several common benign lesions such as a simple anal ulcer, a fibrosed varicosity, an aberrant lymph

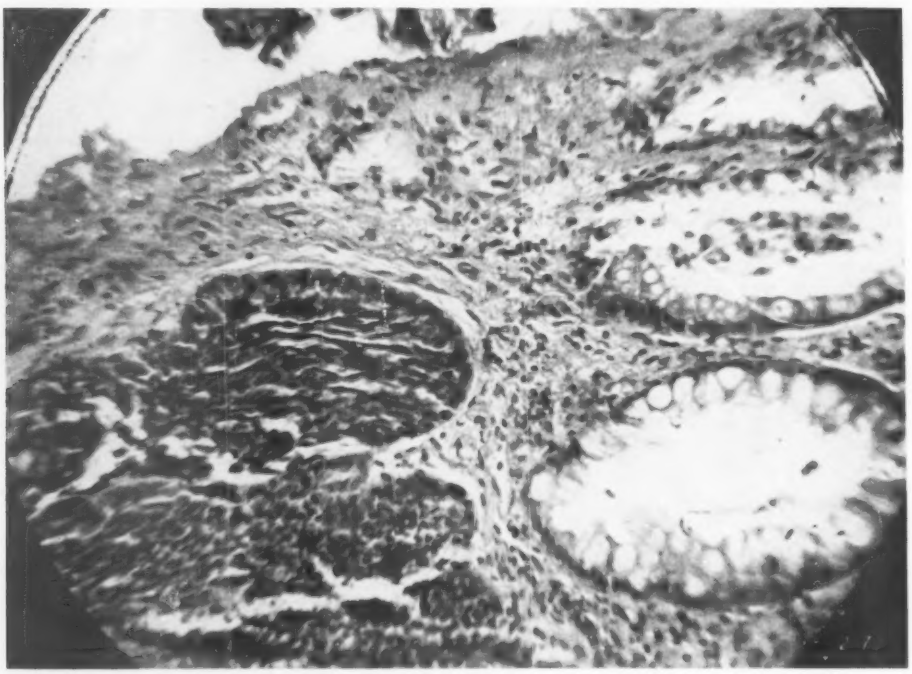

FIG. 1.—Biopsy: basal cell carcinoma beneath mucus glands of the rectal mucosa. The cancer cells are distributed in typical disorderly masses with a single columnar layer of tumor cells at the periphery of the growth. Hematoxylin and phloxine stain. x 274.

node, or even a small, circumscribed, low-grade marginal abscess. Because of the rarety of this tumor, we wish to report another case, with the hope that accumulated experience may lead to improved diagnosis and therapy.

Case Report. K. M., a married, white female, 62 years of age, was seen November 17, 1947. She complained of itching and irritation of the skin around the anus, but only on this date was it severe enough to prompt her to consult her family physician. On routine digital examination this physician noted a little induration beneath the mucosa in the left anterior quadrant between the external and internal sphincters and referred her to one of us (B. D. L.). In the past she had occasionally noticed a trace of fresh,

red blood with bowel movements; she gave no history of passing any old, dark blood or clots. She had no pain with bowel movements, no protrusion except for skin tabs, and no change in bowel habit. She had no previous rectal surgery, no loss of weight, and gave no history of cancer in her immediate family.

Findings. (November 17, 1947) On digital examination a small area of thickening about 1 cm. in diameter could be felt beneath the mucosa at the two o'clock position, at the pectinate line. A biopsy was taken and reported as follows: "Rectal mucosa at the muco-cutaneous junction. There is active mitotic activity but no cell undifferentiation in the squamous epithelium. The sub-epithelial connective tissue contains large pykotic nuclei of doubtful significance. Another biopsy is recommended."

On November 29, 1947, the biopsy was repeated and described as follows: "Rectal mucosa showing chronic inflammation." On December 4, 1947, the patient was referred to the Tumor Clinic at the Binghamton City Hospital for consultation. The Tumor Clinic made this observation and recommendation: "On the left anterolateral wall about 1½ inches from the anal orifice, there is an indurated area about the size of a dime; this is non-tender and feels deep to the mucosa. At the center of the involved area is a small ulceration, likely the site of biopsy. Our impression is of chronic inflammatory tissue following thrombosis and subsequent fibrosis of internal hemorrhoids. This area should be re-checked in three months."

On March 9, 1948, the area of thickening and induration had increased in size, now measuring 2 cm. by 1 cm. A third biopsy was taken and described as follows: "Basal cell carcinoma. The growth in the section lies beneath rectal mucus membrane."

On March 26, 1948, the growth was locally excised and the wound bed generously fulgurated. Microscopic examination of the tissue removed revealed basal cell carcinoma. The growth could not be traced into continuity with any skin appendage. There were also areas of intraepithelial carcinoma in the surface squamous epithelium near the muco-cutaneous junction. By June, 1948, the wound was healed; she was referred for irradiation and received locally, by cone, a total of 5500 r. When last seen in November, 1948, the affected area showed only a small soft scar. She never had palpable inguinal nodes.

SUMMARY

1. With the case described herein, a total of nine cases of basal cell carcinoma of the anus have been reported.

2. With early diagnosis and local surgical excision of the lesion, with or without subsequent irradiation, the prognosis in basal cell cancer of the anus appears to be excellent. The prognosis in advanced lesions appears to be poor.

3. The diagnosis of basal cell carcinoma of the anus may require repeated biopsies of the suspected lesion.

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A COMPACT CAMERA AND LIGHT SOURCE FOR PHOTOGRAPHY UNDER STERILE CONDITIONS*

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A PRACTICAL METHOD for making photographic records of neurosurgical procedures under sterile conditions was described by Ingraham and Cobb in 1947.[1] A 35 mm. camera (Kodak Bantam Special) equipped with a portrait lens was attached at operation to an autoclaved metal frame carrying a sterile cloth cover that could be pulled over the unsterile camera and secured with a drawstring. Focusing was achieved with a rigidly attached metal rod that indicated both the object distance and the center of the lower border of the photographic field. Satisfactory black and white and Kodachrome pictures of a motionless field were obtained with the regular operating room light (Fig. 1).

This equipment is very simply constructed and is relatively easy to operate.† With reasonable care, excellent photographic records may be secured at very low cost. There are, however, certain ready modifications that increase the flexibility of the apparatus.

1. Standard operating room lights illuminate the field somewhat unevenly, have a color temperature different than that for which 35 mm. type A Kodachrome (or other color films) is designed, and are insufficiently intense to allow the rapid exposures required in thoracic and other surgery where motion is a prominent feature. This problem of providing an adequate intensity of color corrected illumination has been resolved in a simple and practical fashion by attaching a mushroom flood bulb (General Electric Photoflood RFL 2) to the camera frame by means of a removable bracket (Fig. 2). The light bulb is screwed into a standard commercial rubber covered socket rendered waterproof by a tightly fitting rubber gasket that surrounds the screw end of the bulb. The light bulb on its bracket is easily detached from the camera frame proper so that it may be sterilized separately by immersion in Zephiran hydrochloride (1 to 1000) (Fig. 3). The camera frame is autoclaved in the usual fashion and the two are reassembled at operation. Control of the camera light in the operating room is secured safely by employing a mercury switch operated with the foot.‡ The camera is first placed in the proper position for the

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† Complete metal frames and cloth covers for several types of 35 mm. cameras are now available at Alfred Bicknell Associates, 243 Broadway, Cambridge, Massachusetts.

‡ A satisfactory mercury type of foot switch is manufactured by C. M. Sorensen, Inc., 403 East 62nd Street, New York 21, New York.

pictures; then only is the foot switch depressed and the picture snapped. The light is on for one to five seconds only and the bulb does not become hot in this brief time.

The light produced by this attached flood bulb is much greater than that secured by more conservative means and is very constant in intensity and quality. Despite the fact that the bulb must be offset somewhat from the axis of the camera lens, the many reflecting surfaces present in the freshly draped operative field cause sufficient light scatter to produce surprisingly flat illumination. Excellent 35 mm. Kodachrome pictures of the rapidly beating dog

FIG. 1 FIG. 2

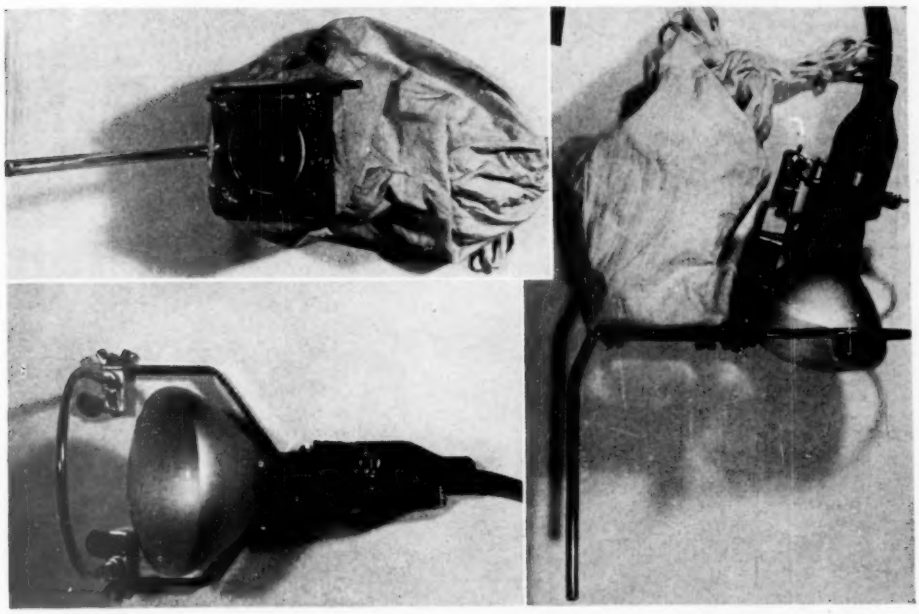

FIG. 3

FIG. 1.—Sterile camera of the Ingraham and Cobb type ready to be used. The cloth bag, metal frame, and glass window completely enclose the camera (Argus C-3). The firmly attached metal rod determines both the object distance and the field size.

FIG. 2.—The same camera shown in Figure 1 with attached light source.

FIG. 3.—The bulb, socket, and bracket shown in Figure 2 have been detached from the camera frame. This requires the loosening of but two wing screws.

heart have been repeatedly obtained in the laboratory with the above equipment, and thoracic vascular procedures have been photographed in the hospital using the camera shown in Figure 5.

The proper speed and diaphragm opening must initially be calculated by trial and error for each photographic field size, but once obtained, may be relied upon. It has been possible, for example, using 35 mm. type A Koda-

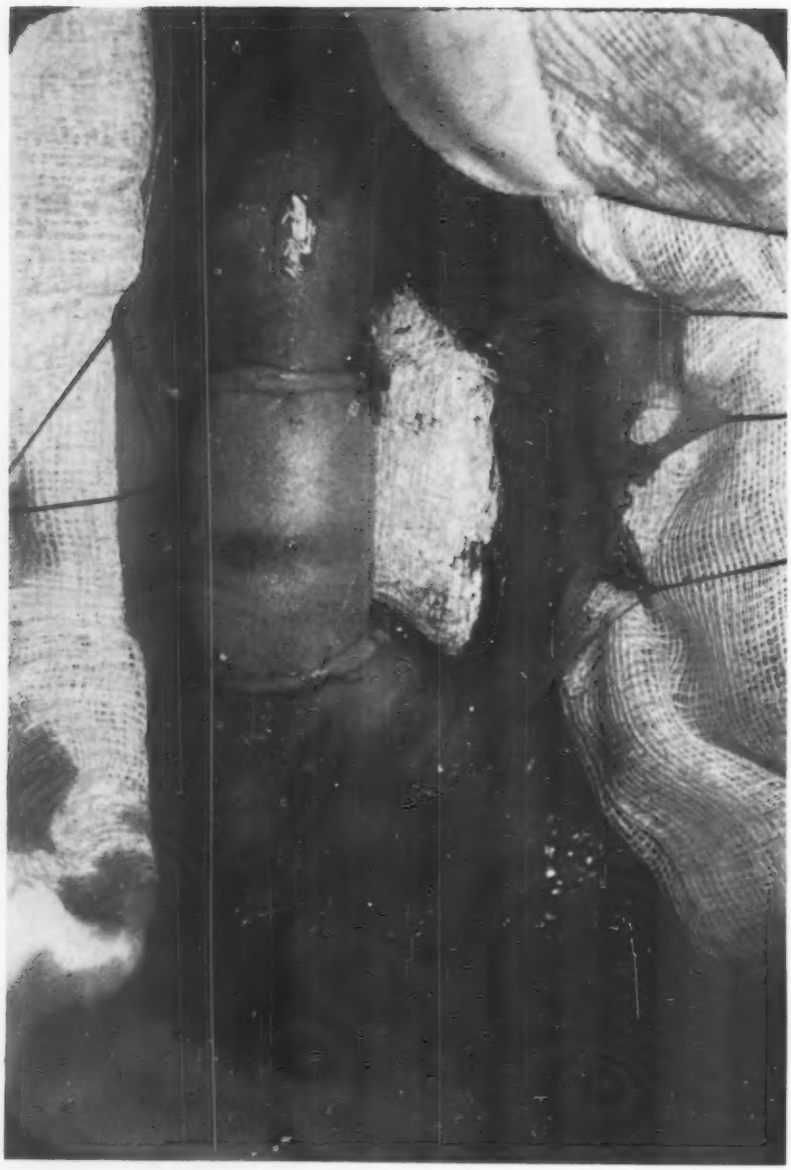

FIG. 4.—Black and white print from an original 35mm. Kodachrome transparency taken under sterile conditions at operation. The picture represents a completed human blood vessel graft for correction of coarctation of the aorta. Approximately natural size. (Courtesy Dr. Robert E. Gross)

chrome, a field of four by six inches, and a diaphragm of f-9 to use shutter speeds of 1/60 to 1/100 second (Fig. 4). Where great depth is desired, the diaphragm may be closed further at the expense of the speed.

2. The field size is limited to approximately six by eight inches when a three diopter "portrait attachment" is used with the 50 mm. focal length lens of a 35 mm. camera, and this is frequently much larger than is desired. By employing a camera with a removable lens such as a Leica, Contax, etc., it is possible to obtain a field of any desired size by simply placing extension tubes of different lengths between the camera and the lens.[2] Proper orientation of the camera with respect to the field to be photographed can be effected by employing replaceable or adjustable metal focusing rods rather than a single

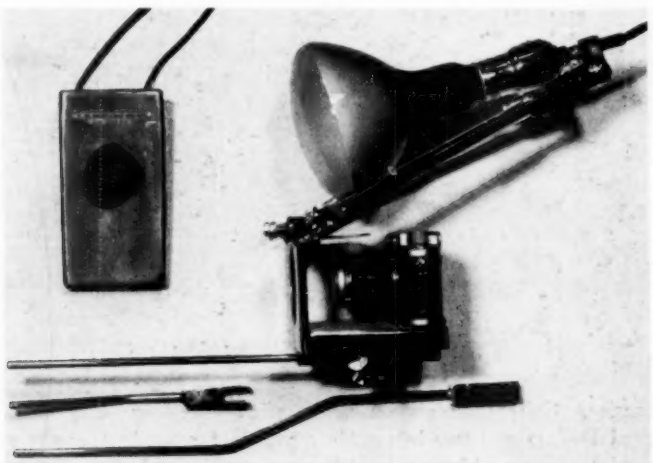

FIG. 5.—Operating room camera modified from Ingraham and Cobb. Note the varying lengths of the focusing rods to conform to different field sizes, the extension tube between camera and lens, and the mercury type of foot switch. This particular camera is operated by an unsterile assistant, only the focusing rod itself being autoclaved. (Courtesy Dr. Robert E. Gross)

fixed one. Figure 5 illustrates a camera recently constructed for maximum versatility. This employs a Leica III with a lens of 50 mm. focal length. The field sizes obtainable vary from one and one-half by two and one-quarter inches to six by nine inches, thus providing a more nearly correct field for varying types of operations and for gross specimens of different dimensions. A satisfactory "sterile" operating room camera with a lens of 73 mm. focal length and a rod adjustable in two planes for different photographic fields has also been used extensively by us. The cameras with removable focusing rods may be operated by an unsterile assistant, only the rods themselves being autoclaved.

SUMMARY

Two modifications of the "sterile" operating room camera designed by Ingraham and Cobb are described. 1. The use of a mushroom photoflood bulb

and bracket sterilizable by immersion in Zephiran and activated by a mercury type of foot switch is discussed. 2. A means of decreasing and varying the photographic field size by employing extension tubes in cameras with replaceable lenses is presented. These modifications greatly enlarge the range of usefulness of the "sterile camera" as a means of recording operative events.

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The Van Meter Prize Award

The American Goiter Association again offers the Van Meter Prize Award of Three Hundred Dollars and two honorable mentions for the best essays submitted concerning original work on problems related to the thyroid gland. The Award will be made at the annual meeting of the Association which will be held in Houston, Texas, March 9, 10 and 11, 1950, providing essays of sufficient merit are presented in competition.

The competing essays may cover either clinical or research investigations; should not exceed 3000 words in length; must be presented in English; and a typewritten double spaced copy in duplicate must be sent to the Corresponding Secretary, Dr. George C. Shivers, 100 East St. Vrain Street, Colorado Springs, Colorado, not later than January 15, 1950. The committee, who will review the manuscripts, is composed of men well qualified to judge the merits of the competing essays.

A place will be reserved on the program of the annual meeting for presentation of the Prize Award Essay by the author, if it is possible for him to attend. The essay will be published in the annual Proceedings of the Association.

Editorial . . .

The Full-Time Teacher of Surgery

A LITTLE MORE THAN 35 YEARS have now elapsed since the General Education Board appropriated funds for carrying out the "full-time scheme" for clinical education and research at Johns Hopkins. It was an action received with great enthusiasm by some and marked hostility by others. Few, indeed, interested in medical education remained neutral. Such was not unexpected, for the fact that the entire staff in the clinical branches should devote full time to teaching and research seemed to many revolutionary in scope; and the medical profession, as a rule, accepts revolutionary changes with what often is a tantalizing hesitation.

Whether the full-time teacher was to be the answer or not, many thoughtful people at that time realized that the clinical departments in our medical schools were in bad need of reform. As a rule, the clinical chief had been the successful local practitioner in his community. When he received his appointment, he retained it until retirement or death intervened. Because he was a successful practitioner, he usually was a busy practitioner; and because of the pressure of time his teaching generally consisted of a series of lectures, clinical demonstrations, or operations. To pursue the scientific side of surgery without adequate time, facilities or budget was indeed difficult. In a period of great scientific achievement, this obviously was an impossible situation. With sciences such as physiology, physiologic chemistry, pathology, and bacteriology making rapid strides, it was patent that soon the surgeon must be cognizant not only with their advances in order to adapt them to his profession but that he also must be a participant in these advances.

Just when the unrest began is hard to state. In Germany in particular, the participation of the surgical teacher in the study of pathology and bacteriology and the withdrawal from a consultative practice was becoming more and more frequently seen. In this country Mall played an important part, bringing back as he did the enthusiasm that was generated by Ludwig and his group in their consideration of clinical medicine as a biologic science. Certainly Mall was a great stimulus, along with Barker, to the group in Chicago, and he carried this fire with him to Johns Hopkins. However, it is perhaps to the vision and tenacity of Welch and the sympathy and sagacity of Gates and Abraham Flexner of the General Education Board that this plan was put in practice in this country as rapidly as it was. During its incubation, however, through the early years of this century, many important medical educators made statements favoring such a form of teaching, some in definite phrases, and others more haltingly.

Although he subsequently came to lose much of his enthusiasm for the full-time plan, the theoretical advantages were expressed by Barker as giving

clinical teachers adequate material on the wards, laboratory facilities, and time for thinking, research, and teaching. On those rare occasions in which the clinical head would find it necessary to take care of a patient with means to pay, the fee would be placed in the treasury of the university. This would throw the accent in the clinical departments on scientific study of the ill person and by so doing would stimulate the undergraduate and graduate student of medicine to further advances in the adaptation of the preclinical sciences to the hospital ward.

This idealism was challenged by the Council of the American Medical Association in its report in 1914. While it granted that the clinical professor should be a great physician, a well-trained teacher, and a research worker, the Council favored the adoption in this country of the system extant in Germany at that time in which the clinical professorship was vested with all of the prerogatives of any other university professorship but the individual occupying the chair was allowed to support himself and his department by private practice. They felt that having the head of the department receive no fees and turning the income from his private consultations in to the university treasurer was "grotesque."

Even Welch noted objections to the proposal which he so ably championed. He felt that there would be difficulty in securing and holding the very best men with such salaries as could be paid, and at the same time he felt "it would be hazardous to start the new arrangement with young men in the clinical chairs without considerable experience and without established reputations, however promising they may be." He also was aware of the danger of private practice with a man of such reputation and felt "that the number of these private patients should be limited and determined mainly by the scientific interests of the cases." He also noted that since the attraction of these clinical chairs would be an opportunity for a high type of scientific work and not salary, it was important that the occupants not be "overburdened with administration, teaching, and the care of patients."

Even the most enthusiastic champion of the full-time system felt the inadvisability of excluding the excellent clinical teacher who, to a large extent, was engaged in private practice. He was to give part of his time to teaching, for not only were there many such excellent teachers but this plan would make the budgetary demands not too formidable.

The original plan obviously was an experiment. Since its inception, however, it has been adopted in principle by many institutions in this country, although often there have been modifications. Its effect on medical education undoubtedly has been profound, and the caliber of scientific investigation, teaching, and clinical care emanating from such departments of surgery has been outstanding. A new generation of surgeons has arisen in this country, and the American universities have become the mecca of the surgical world. One, however, should not be too enthusiastic in giving all of the credit to this full-time system, for there are too many brilliant exceptions. Important con-

tributions to the science of surgery have been made by the so-called part-time surgeon as well as in some of our great surgical clinics where there is no undergraduate instruction. There also are many departments of surgery adhering more or less to the old Germanic system that could well be envied by departments manned by full-time professors. The achievements of a great individual should not be credited to a system, for he probably would have done as well under any of the systems, providing adequate facilities were available.

Full-time surgical education undoubtedly has added greatly to the expense of conducting a medical school. During that period of American life in which endowments brought in good returns and in which the wealthy frequently gave large sums of money to medical schools, this rise in cost, to a large part, could be defrayed by increase in income. This source of revenue now is dwindling rapidly. Many schools, therefore, particularly those that are privately endowed, are being confronted with the problem of how to maintain full-time teachers in clinical medicine. So great is this financial burden that once again the question is arising as to whether or not it is desirable that this be done. Complicating the situation even further has been the growth of group practice systems in this country, health and hospital insurance schemes, and a definite desire on the part of the public to provide better medicine and surgery to more people. These complexities make the dilemma being drawn now almost as great as in the beginning, if not more so. The answer to this problem is evolving apparently in three different directions.

The simplest solution is to abolish full-time departments and institute a chair of surgery that carries with it a token salary and allow the professor independence in so far as his surgical practice and private income are concerned. Although immediately there would be a conflict between a demanding private practice and an academic conscience, it is felt by many that with the right type of man occupying the professorial chair this difficulty could be resolved. There are those who feel that such a scheme would work just as well in this country now as it did in Germany two generations ago. Others feel that such a professorship would once again lag too far behind in the sensitive awareness of those sciences basic to surgery.

Another suggestion that has been made also has an element of simplicity: let the federal government finance full-time medical education. Yet to many this would be not only a misuse of public funds but would carry with it an administrative rigidity and administrative obligations that would defeat the very purpose for which full-time clinical departments were established. The restrictions on academic freedom that so often come with various forms of "statism" are still undesired by many.

Finally, full-time departments of clinical surgery can continue to obtain whatever funds they can from outside benevolent sources and at the same time increase the number of private patients seen in order to increase the income of the department. Such funds could easily be used not only to support

the salary of the professor of surgery but also to make it possible for many younger surgeons interested in a scientific career to stay in academic institutions for a longer period of time. During recent years many good institutions in this country have tended toward this latter solution of the problem. Whether this will be successful or not remains to be seen. This, again, is an experiment and one that is well worth adequate trial. The danger, of course, is one of exploitation of the surgeon by the university, for obviously the patients seen will not be limited to those of scientific interest as Welch had once hoped. This exploitation can be limited, even stringently, by the number of private beds available. Another safeguard will be the fact that if the professor of surgery is forced into spending too much of his time in private surgical care the position at that university will lose its attraction for men of great scientific bent and teaching interests. Perhaps a certain amount of exploitation on the part of the university may be justified, for a great university gives much to its professor of surgery in terms of prestige and renown; and who will deny that the care of a few private patients is an enriching experience for the full-time professor?

The solution to the problem of surgical teaching in our universities probably should not be a stereotyped one applicable equally to all universities. It will be necessary for many experiments to be tried in many different environments. There is little to be gained by giving vent to one's emotions in the solution of these problems, but there is much to be offered in consultation between different universities discussing different methods, their problems, and their possible solutions. The problem will always be a dynamic one and will change with the changes in economic and social conditions in our country.

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INDEX TO VOLUME 130

A

Abdomen, Emphysematous, Acute, and Subcutaneous Emphysema from Intrarectal Operation, 277.

Abdominal Adhesions, Effect of Diathermy upon, 937.

Acoustic Tumors, End Results of Complete Versus Intracapsular Removal of, 567.

Acute Pancreatitis, 1044.

Adenoma, Islet-cell, Total Pancreatectomy for Hyperinsulinism due to, 211.

Amputation, Transmetatarsal, for Infection or Gangrene in Patients with Diabetes Mellitus, 826.

Anastomosis, Cervical, Esophagogastric, Following Subtotal Resection of the Esophagus for Carcinoma, 1; Elliptical, in Urologic Surgery, 796.

Aneurysm of the Common Carotid Artery, 913.

Announcements: Kappa Delta Award for Research in Orthopedic Surgery, 144; The Van Meter Prize Award, 1108.

Anus, Basal Cell Carcinoma of the, 1101.

Aorta, Coarctation of, at the Level of the Diaphragm, 1091; and Great Vessels, an Aid for the Contrast Visualization of The Valsalva Maneuver, 398; Surgical Treatment of Insidious Thrombosis of, 417; Thoracic, Experimental Evaluation of Certain Methods of Suturing the, 363.

Appendiceal Calculi, 975.

Arterial Injuries, Quantitative Studies on the Time Factor in, 428.

Arteries, Uses of Plastic Tubes in the Reparative Surgery of Battle Injuries to, with and without Intra-arterial Heparin Administration, 1024.

Atlas, Isolated Fracture of, 261.

Atomic and Vocational Exposures to Radiation Burns, 593.

Aureomycin, Streptomycin and Chloromycetin: Experimental and Clinical Comparison, 576.

B

Bacitracin, Use of, in Experimental *Cl. Welchii* Infection in Guinea Pigs, 674.

Basal Cell Carcinoma of the Anus, 1101.

Belching, Observations on, during Anesthesia, Operations and Pyelography, 512.

Bilateral Broad Ligament Lipomata, 281.

Bile Duct, Common, Physiologic Studies in Cases of Stricture of, 448.

Biliary Fistula, Spontaneous, Internal, 270.

Biliary Obstruction, Intrahepatic Cholangiojejunostomy for, 455.

Blood Stasis in the Lungs as a Factor in the Etiology of Postoperative Pulmonary Complications, 790.

Bone, Fibrous Dysplasia of, 881; Innominate, Disarticulation of, for Primary and Metastatic Cancer, 76.

Book Reviews: Preoperative and Postoperative Care of Surgical Patients, 143; Review of Acute Intestinal Obstruction, 143; Shock and Allied Forms of Failure of the Circulation, 288; Surgical Pathology, 592; The Thyroid and its Diseases, 592.

Bowel, Large, Complete Duplication of, Treated by Subtotal Colecstomy, 249.

Brain, Exposed, Effects of Ultraviolet Radiation on the, 68; Tumors of, Clinical Use of Radioactive Phosphorus in Surgery of, 643.

Breast, Cancer of, 310; Carcinoma of, "Categorically Inoperable," 38.

Burns Unit, Mortality in, 160.

C

Calculi, Appendiceal, 975.

Cancer, of the Breast, 310; of the Colon and Rectum, Some Reflections on Surgical Principles in Treating, 1008; Gastric, Postoperative Diabetes Mellitus Following Resection of the Body and Tail of the Pancreas for Secondary Invasion by, 921; Primary and Metastatic, Disarticulation of an Innominate Bone for, 76.

Cancer Research Program, Development of New Methods for the Histochemical Demonstration of Hydrolitic Intracellular Enzymes in a, 333.

Carcinoma, Basal Cell, of the Anus, 1101; of the Breast, "Categorically Inoperable," 38; of the Cervical Esophagus, One-stage Resection with Subpharyngeal Esophagogastrostomy, 9; of Esophagus, Cervical Esophagogastric Anastomosis Following Subtotal Resection, 1; of the Lower Lip, 896; Primary, of the Duodenum, 253; Primary, of the Ureter, 902; Rectal, as Related to the Anatomy of the Lymphatics, Sphincter Preserving Operations for, 538; of the Stomach, Extension of, into the Duodenum and Esophagus, 557; Supra-aortic, Cervical Esophagogastrostomy Following Resection of the Esophagus for, 21.

Carotid Artery, Common, Aneurysm of, 913.

"Categorically Inoperable" Carcinoma of the Breast, 38.

Cause of Death in Strangulation Obstruction, 857, 874.

Cervical Esophagogastric Anastomosis Following Subtotal Resection of the Esophagus for Carcinoma, 1.

Cervical Esophagogastrostomy Following Resection of Supra-aortic Carcinoma of the Esophagus, 21.

Chloride, Glucose, Potassium, Sodium and Parenteral Water, Minimum Postoperative Maintenance Requirements for, 703.

Chloromycetin, Aureomycin and Streptomycin: Experimental and Clinical Comparison, 576.

Cholangiojejunostomy, Intrahepatic, for Biliary Obstruction, 455.

Chronic Stenosing Regional Enteritis—Surgical Pathology and Experience in Surgical Treatment, 233.

Circulation of the Small Intestine, 608.

Clinical and Experimental Studies of Fluorescein Dyes with Special Reference to their Use for the Diagnosis of Central Nervous System Tumors, 637.
Clinical Evaluation of Two Tests for Incipient Thrombosis, 439.
Clinical Use of Polyethylene Tubing for Intravenous Therapy, 929.
Clinical Use of Radioactive Phosphorus in the Surgery of Brain Tumors, 643.
Clostridium Welchii Infection in Guinea Pigs, Experimental, Use of Bacitracin in, 674.
Coarctation of the Aorta at the Level of the Diaphragm, 1091.
Colectomy, Subtotal, Complete Duplication of the Large Bowel Treated by, 249.
Colon, Diverticulitis of, 983; and Rectum, Reflections on Surgical Principles in Treating Cancer of, 1008.
Combination Probe, Dilator and Irrigator for Common Duct Surgery, 980.
Compact Camera and Light Source for Photography under Sterile Conditions, 1104.
Complete Duplication of the Large Bowel Treated by Subtotal Colecstomy, 249.
Complications of Gastro-intestinal Intubation, 113.
Congestion in the Pulmonary Circulation in Cases of Severe Mitral Stenosis, Surgical Relief of, 384.

D

Deaths, Cause of, in Strangulation Obstruction, 857, 874; Postoperative, 589.
Deperitonealization: Clinical and Experimental Observations, 466.
Development of New Methods for the Histochemical Demonstration of Hydrolytices Intracellular Enzymes in a Program of Cancer Rsearch, 333.
Diabetes Mellitus, Postoperative, Following Resection of the Body and Tail of the Pancreas for Secondary Invasion by Gastric Cancer, 921; Transmetatarsal Amputation for Infection or Gangrene in Patients with, 826.
Diaphragm, Coarctation of the Aorta at the Level of the, 1091.
Diaphragmatic Hernia with Complete Evisceration of the Liver, 1079.
Diathermy, Effect of, Upon Abdominal Adhesions, 937.
Dicumarol, Effect of, upon Postoperative Peritoneal Adhesions, 942.
Disarticulation of an Innominate Bone for Primary and Metastatic Cancer, 76.
Diverticulitis of the Colon, 983; of the Sigmoid Colon, Sigmoido-vesical Fistulae Resulting from, 186.
Duodenal Ulcer, Surgical Treatment of—Comparison of Results with and without Vagotomy, 31.
Duodenum, Primary Carcinoma of, 253; and Esophagus, Extension of Carcinoma of the Stomach into, 557.
Dysplasia, Fibrous, of Bone, 881.

E

EDITORIALS: Diverticulitis of the Colon, 983; General Surgical Training and the Specialties, 284; Postoperative Deaths, 589; The Full-time Teacher of Surgery, 1109; The Inquiring Mind, 137; The Place of Research in a Surgical Training Program, 855
Effect of Diathermy upon Abdominal Adhesions, 937
Effect of Dicumarol upon Postoperative Peritoneal Adhesions, 942.
Effect of Heparin on Gelatin Sponge Hemostasis, 948.
Effects of Ultraviolet Radiation on the Exposed Brain, 68.
Elliptical Anastomosis in Urologic Surgery, 796.
Emphysema, Subcutaneous, and Emphysematous Acute Abdomen from Intrarectal Operation, 277.
Emphysematous Acute Abdomen and Subcutaneous Emphysema from Intrarectal Operation, 277.
End Results of Complete Versus Intracapsular Removal of Acoustic Tumors, 567.
Enteritis, Chronic, Stenosing, Regional, 233.
Enzymes, Hydrolytic, Intracellular, in a Program of Cancer Research, Development of New Methods for the Histochemical Demonstration of, 333.
Erythrocytes, Infused, Metabolic Fate of, 723; Lysed, Factors Inducing Renal Shut-down from, 49.
Esophagectomy, Transthoracic, Gastropericardial Fistula Following, 1074.
Esophagogastrostomy, Cervical, Following Resection of Supra-aortic Carcinoma of the Esophagus, 21; Subpharyngeal, One-stage Resection of Carcinoma of the Cervical Esophagus with, 9.
Esophagus, Cervical, Carcinoma of, One-stage Resection of, with Subpharyngeal Esophagogastrostomy, 9; Cervical Esophagogastrostomy Following Resection of Supra-aortic Carcinoma of the 21; and Duodenum, Extension of Carcinoma of the Stomach into the, 557; Spontaneous Rupture of the, 1066; Subtotal Resection of, for Carcinoma, Cervical Esophagogastric Anastomosis Following, 1.
Evacuation of Traumatic Extradural Hemorrhage from the Posterior Fossa, 963.
Evaluation of Oxygen Therapy, 747.
Evaluation of Total Sympathectomy, 652.
Experimental Evaluation of Certain Methods of Suturing the Thoracic Aorta, 363.
Experimental Study of Flash-burns, 774.
Extension of Carcinoma of the Stomach into the Duodenum and Esophagus, 557.
Exteriorization of the Canine Vesical Trigone for Experiments on the Kidney, 43.

F

Factors Inducing Renal Shut-down from Lysed Erythrocytes, 49.
Fibrous Dysplasia of Bone, 881.
Flash-burns, Experimental Study of, 774.
Fluorescein Dyes, Clinical and Experimental Studies of, with Special Reference to their Use for the Diagnosis of Central Nervous System Tumors, 637.
Fracture, Isolated, of the Atlas, 261.
Further Experiences with Streptomycin Therapy in Peritonitis, 242.

G

Gangrene and Infection in Patients with Diabetes Mellitus, Trans-metatarsal Amputation for, 826.
Gas, Gastro-intestinal, 512.
Gastric Cancer, Postoperative Diabetes Mellitus Following Resection of the Body and Tail of the Pancreas for Secondary Invasion by, 921.
Gastric Ulcer, Recurrence of, after Complete Vagotomy, 843.
Gastro-ileostomy, Inadvertent, 124.
Gastro-intestinal Gas, 512.
Gastro-intestinal Intubation, Complications of, 113.
Gastropericardial Fistula Following Transthoracic Esophagectomy, 1074.
Gelatin Sponge Hemostasis, Effect of Heparin on, 948.
Glucose, Chloride, Potassium, Sodium and Parenteral Water, Minimum Postoperative Maintenance Requirements for, 703.

H

Hemipelvectomy for Primary and Metastatic Cancer, 76.
Hemorrhage, Traumatic, Extradural, Evacuation of, from the Posterior Fossa, 963.
Hemostasis, Gelatin Sponge, Effect of Heparin on, 948.
Heparin, Administration of, Intra-arterial, Uses of Plastic Tubes in Reparative Surgery of Battle Injuries to Arteries with and without, 1024; Effect of, on Gelatin Sponge Hemostasis, 948.
Hernia, Diaphragmatic, with Complete Evisceration of the Liver, 1079.
Herpes Zoster: A Surgical Procedure for the Treatment of Posttherpetic Neuralgia, 622.
Hourglass Stomach Caused by Annular Muscular Hypertrophy, 1085.
Hyperinsulinism Due to Islet-cell Adenoma, Total Pancreatectomy for, 211.
Hypertension, Intrathoracic Pheochromocytoma with, 1059; Portal, Sarcoidosis Producing, 951
Hyperthyroidism, Pathogenesis of, 804.
Hypertrophy, Annular, Muscular, Hourglass Stomach Caused by, 1085.

I

Inadvertent Gastro-ileostomy, 124.
Infants and Children, Intussusception in, 200.
Intestinal Obstruction in the Newborn, 480.
Intestine, Small, Circulation of, 608.
Intrahepatic Cholangiojejunostomy for Biliary Obstruction, 455.
Intrarectal Operation, Emphysematous Acute Abdomen and Subcutaneous Emphysema from, 277.
Intrathoracic Pheochromocytoma with Hypertension, 1059.
Intravenous Therapy, Clinical Use of Polyethylene Tubing for, 929.
Intussusception in Infants and Children, 200.
Isolated Fracture of the Atlas, 261.

K

Kidney, Exteriorization of the Canine Vesical Trigone for Experiments on the, 43.

L

Lesions, Chronic, Resulting from Radiation Burns, Surgical Prevention of, 593.
Letter to the Editor, 140.
Lip, Lower, Carcinoma of, 896.
Liptomata, Bilateral, Broad Ligament, 281.
Liver, Diaphragmatic Hernia with Complete Evisceration of the Liver, 1079.
Lungs, Blood Stasis in, as a Factor in the Etiology of Postoperative Pulmonary Complications, 790.
Lymphatics, Sphincter Preserving Operations for Rectal Carcinoma as Related to the Anatomy of the, 538.

M

Macrostomia, Unilateral, 1098.
Malignant Melanoma, 318.
Masculinizing Tumor of the Ovary, 967.
Mechanism of the Post-gastrectomy "Dumping" Syndrome, 145.
Melanoma, Malignant, 318.
Metabolic Fate of the Infused Erythrocyte, 723.
Miller-Abbott Tube, an Unusual Experience with, 267.
Minimum Postoperative Maintenance Requirements for Parenteral Water, Sodium, Potassium, Chloride, and Glucose, 703.
Mitral Stenosis, Severe, Surgical Relief of Congestion in the Pulmonary Circulation in, 384.
Mortality in a Burns Unit, A Study of, 160.

N

Nervous System, Central, Clinical and Experimental Studies of Fluorescein Dyes with Special Reference to their Use for the Diagnosis of Tumors of, 637.
Neuralgia, Postherpetic, a Surgical Procedure for, 622.
Newborn, Intestinal Obstruction in, 480.
Nitrogen Loss, Postoperative, 688.
Obstruction of the Inferior Vena Cava above the Renal Veins, 958.
One-stage Resection of Carcinoma of the Cervical Esophagus with Subpharyngeal Esophagogastrostomy, 9.

O

Ovary, Masculinizing Tumor of, 967.
Oximetry, Sources of Error in, 755.
Oxygen Therapy, Evaluation of, 747.

P

Pancreas, Postoperative Diabetes Mellitus Following Resection of the Body and Tail or, for Secondary Invasion by Gastric Cancer, 921.

Pancreatectomy, Total, for Hyperinsulinism due to Islet-cell Adenoma, 211.
Pancreatitis, Acute, 1044.
Parenteral Water, Sodium, Potassium, Chloride and Glucose, Minimum Postoperative Maintenance Requirements for, 703.
Patent Ductus Arteriosus, the Surgery of, 174.
Pathogenesis of Hyperthyroidism, 804.
Peptic Ulcer, Limitations of Vagotomy in the Treatment of, 985.
Peritoneal Adhesions, Postoperative, Effect of Dicumarol upon, 942.
Peritonitis, Further Experiences with Streptomycin Therapy in, 242.
Pheochromocytoma, Intrathoracic, with Hypertension, 1059.
Photography under Sterile Conditions, A Compact Camera and Light Source for, 1104.
Physiologic Studies in Cases of Stricture of the Common Bile Duct, 448.
Polyethylene Tubing for Intravenous Therapy, the Clinical Use of, 929.
Posterior Fossa, Evacuation of Traumatic Extradural Hemorrhage from the, 963.
Post-gastrectomy "Dumping" Syndrome, Mechanism of, 145.
Postoperative Deaths, 589.
Postoperative Diabetes Mellitus Following Resection of the Body and Tail of the Pancreas for Secondary Invasion by Gastric Cancer, 921.
Postoperative Nitrogen Loss, 688.
Potassium, Sodium, Parenteral Water, Chloride and Glucose, Minimum Postoperative Maintenance Requirements for, 703.
PRESIDENTIAL ADDRESS: Mission Accomplished: The Task Ahead, 289.
Primary Carcinoma of the Duodenum, 253; of the Ureter, 902
Pulmonary Circulation, Congestion in, in Cases of Severe Mitral Stenosis, Surgical Relief of, 384.
Pulmonary Complications, Postoperative, Blood Stasis in the Lungs as a Factor in the Etiology of, 790.
Pulmonary Stenosis, Congenital, Surgical Treatment of, 342.

Q

Quantitative Studies on the Time Factor in Arterial Injuries, 428.

R

Radiation Burns, Including Vocational and Atomic Exposures: Treatment and Surgical Prevention of Chronic Lesions, 593.
Radioactive Phosphorus, Clinical Use of, in the Surgery of Brain Tumors, 643.
Rectum and Colon, Reflections on Surgical Principles in Treating Cancer of, 1008.
Recurrence of Gastric Ulcer after Complete Vagotomy, 843.
Renal Shut-down, Factors Inducing, from Lysed Erythrocytes, 49.
Renal Veins, Obstruction of the Inferior Vena Cava above the, 958.
Resection, One-stage, of Carcinoma of the Cervical Esophagus with Subpharyngeal Esophagogastrostomy, 9; Subtotal, of the Esophagus for Carcinoma, Cervical Esophagogastric Anastomosis Following, 1; of Supra-aortic Carcinoma of the Esophagus, Cervical Esophagogastrostomy Following, 21.

S

Sarcoidosis Producing Portal Hypertension, 951.
Sigmoid Colon, Sigmoidovesical Fistulae Resulting from Diverticulitis of the, 186.
Sigmoidovesical Fistulae Resulting from Diverticulitis of the Sigmoid Colon, 186.
Sodium, Potassium, Chloride, Glucose and Parenteral Water, Minimum Postoperative Maintenance Requirements for, 703.
Some Limitations of Vagotomy in the Treatment of Peptic Ulcer, 985.
Some Reflections on Surgical Principles in Treating Cancer of the Colon and Rectum, 1008.
Sources of Error in Oximetry, 755.
Sphincter Preserving Operations for Rectal Carcinoma as Related to the Anatomy of the Lymphatics, 538.
Spontaneous Internal Biliary Fistula, 270.
Spontaneous Rupture of the Esophagus, 1066.
Stomach, Extension of Carcinoma of, into the Duodenum and Esophagus, 557; Hourglass, Caused by Annular Muscular Hypertrophy, 1085.
Strangulation Obstruction, Cause of Death in, 857, 874.
Streptomycin, Aureomycin and Chloromycetin: Experimental and Clinical Comparison, 576.
Streptomycin Therapy in Peritonitis, Further Experiences with, 242.
Stricture of the Common Bile Duct, Physiologic Studies in, 448.
Study of Mortality in a Burns Unit, 160.
Surgery of Brain Tumors, Clinical Use of Radioactive Phosphorus in, 643; of the Common Duct, A Combination Probe, Dilator and Irrigator for, 980; of Patent Ductus Arteriosus, 174; Reparative, of Battle Injuries to Arteries with and without Intra-arterial Heparin Administration, Uses of Plastic Tubes in, 1024.
Surgical Prevention of Chronic Lesions from Radiation Burns, 593.
Surgical Relief of Congestion in the Pulmonary Circulation in Cases of Severe Mitral Stenosis, 384.
Surgical Training, General, and the Specialties, 284.
Surgical Treatment of Congenital Pulmonary Stenosis, 342; of Duodenal Ulcer—Comparison of Results with and without Vagotomy, 31; of Insidious Thrombosis of the Aorta, 417.
Suturing the Thoracic Aorta, Experimental Evaluation of Certain Methods of, 363.
Sympathectomy, Total, Evaluation of, 652.

T

Talc Granuloma—A Survey of Its Incidence and Significance, 100.

Thoracic Aorta, Experimental Evaluation of Certain Methods of Suturing the, 363.
Thrombosis, Incipient, Clinical Evaluation of Two Tests for, 439; Insidious, of the Aorta, Surgical Treatment of, 417.
Total Pancreatectomy for Hyperinsulinism due to Islet-cell Adenoma, 211.
Transmetatarsal Amputation for Infection or Gangrene in Patients with Diabetes Mellitus, 826.
Tumors, of the Central Nervous System, Clinical and Experimental Studies of Fluorescein Dyes with Special Reference to their Use for the Diagnosis of, 637; Masculinizing, of the Ovary, 967.

U

Ultraviolet Radiation, Effects of, on the Exposed Brain, 68.
Unilateral Macrostomia, 1098.
Unusual Experience with the Miller-Abbott Tube, 267.
Ureter, Primary Carcinoma of, 902.
Urologic Surgery, Elliptical Anastomosis in, 796.
Use of Bacitracin in Experimental *Cl. Welchii* Infection in Guinea Pigs, 674.
Uses of Plastic Tubes in the Reparative Surgery of Battle Injuries to Arteries with and without Intra-arterial Heparin Administration, 1024.

V

Vagotomy, Comparison of Results with and without, in the Surgical Treatment of Duodenal Ulcer, 31; Complete, Recurrence of Gastric Ulcer after, 843; Limitations of, in the Treatment of Peptic Ulcer, 985.
Valsalva Maneuver: An Aid for the Contrast Visualization of the Aorta and Great Vessels, 398.
Varicose Veins, 218.
Vena Cava, Inferior, Obstruction of, above the Renal Veins, 958.
Vesical Trigone, Canine, Exteriorization of, for Experiments on the Kidney, 43.

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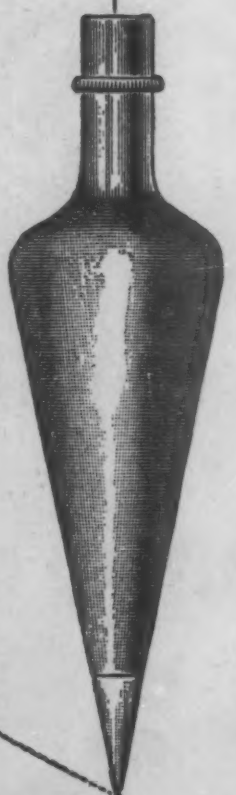

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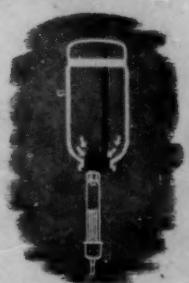

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